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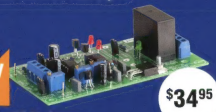

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Publisher's Letter

We live in a time of plenty and we should all be optimistic

Do you get sick of all the bad news on the media? Every day there seems to be another dire story about things getting worse: more pollution, more floods, more fires, deaths, more noise, more disease, scarcer resources, energy becoming more expensive – the list goes on and on. And yet for the vast majority of people, life is not getting worse, life is getting better; profoundly so.

Consider, for example, the increasing cost of energy and in particular, the burden that air-conditioners place on our electricity grid. For me, that burden is not bad; that is good. Fifty or sixty years ago in Australia virtually no households had air-conditioning; not even the richest people had it. The same applied to most office buildings. So in summer we all sweltered and many older people died of heat stress. In winter, we shivered and older people were more likely to die of cold or succumb to influenza.

But now, most households can afford air-conditioning and unless people are living in areas where they get cooling sea breezes in summer, they elect to have it. And nor do they necessarily moan about the resulting electricity bills. You want the comfort? That's what it costs! Really, the only argument is whether the electricity tariffs should be as high as they are. I would argue that they are artificially high, partly because of subsidies for renewable energy. But by and large, most people are significantly more comfortable, happier and probably live longer because of air-conditioning. It is a blessing.

And what about air and water pollution, soil degradation, desertification and so on? Again, it is pretty easy to gain the impression that everything is getting worse. Well, in the cities of most developed countries of the world, air and water pollution is demonstrably better than it was in past decades. Similar comments apply to soil degradation. Better farming techniques in the advanced countries are slowing the process of soil degradation and as living stands rise in the developing countries, you can see the process of improvement again, with China being a prime example.

And think about the range of entertainment that we now have. Fifty years ago in Australia, we did have black and white television in the cities but many households did not have it. Nor did most households have hifi systems. Indeed, many homes did not even have a telephone. Microwave ovens, dishwashers, automatic washing machines, clothes dryers – what were they? Computers, smart phones? – science fiction! And what about developments in medicine with heart, lung, kidney and even liver transplants, hip and knee replacements and so on? Now look at us! The march of technology has brought unimaginable improvements to virtually every aspect of our lives – at least they were unimaginable fifty or more years ago.

So why is the news so dire? Why are some people so worried about resources getting scarcer or climate change? As far as natural resources are concerned, I cannot think of one that is becoming scarcer. Sure, fish stocks have been badly depleted in parts of the world but I have no doubt that, with the move to large-scale fish farming, even that may be reversed in the future. After all, look at the rising whale numbers around the world.

Which finally brings me to climate change. Why are we so worried? In the past, human ingenuity has adapted to much more adverse conditions and man has thrived. I have no doubt that the wonders of technology over the next fifty years will again bring unimaginable improvements to our lives. We couldn't imagine them in the past and we cannot necessarily imagine future improvements right now, can we? Be optimistic; I certainly am.

Leo Simpson

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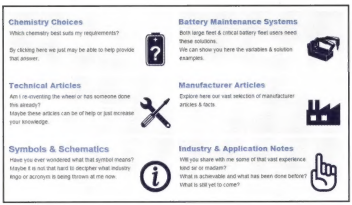

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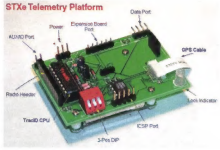
Help required for kite record attempt

My world altitude record was included in "Reach For The Sky" in the February 2015 issue; excellent article by the way! I am by no means an electronics expert and have a basic understanding of radio, GPS and telemetry. In 2006 I purchased a GPSFlight telemetry system from the USA. This includes on-board 900MHz spread spectrum Maxstream radios coupled to a u-blox GPS receiver. The ground transceiver is a Maxstream connected to a PC Win 7 laptop via USB.

The flight module was troublesome for a couple of years, with two replacement units, however the original interface board had auxiliary pins for a barometric altitude module (BAM) and a temperature module. Unfortunately, these units were lost in return mail to the USA. My current board has six spare pins and I am assuming these are for those auxiliary modules.

GPSFlight suffered in the GFC and has closed. The last units available about three years ago had the optional modules listed. I am hopeful of finding temperature and barometric modules that may work but the temperature is most important as we plan on flying a train of big kites to over 40,000 feet.



The software that interfaces with the telemetry is called GPSFlight Dashboard (the free version) and GPS Team, the fully featured version. Both these have barometric and temperature on their displays. These spare pins show about 3V. I was hoping that suitable modules would be available and work on my boards. I have seen various small OEM modules but I have no idea how they would interface with the board or the software.

I have found images of the 2003 GPSFlight interface board as well as the optional Baro sensor PCB, although the latter is quite blurred. It has six pins on one side and three on the other. I'm looking for a pin assignment diagram but it's difficult as the company shut three years ago.

The 2006 version is fairly close to this design but has another row of three pins in the middle of the interface board. I don't know what goes on the 2-pin auxiliary. I was hoping that your team or readers may have some ideas.

Bob Moore,
Baulkam Hills, NSW.

Teething problems with the $5 Wifi Server

I had some trouble setting up the $5 WiFi server described in the December 2014 issue and the following tips may help others. The connection diagram of Fig.4 on page 32 contains an error. The Micromite COM1: TRANSMIT is shown as pin 23 but is actually pin 21.

The Terminal Program listed on page 35 opens COM1 at 115,200 baud whereas the ESP8266 modules I purchased (vendor: **www.ai-thinker.com Version:0.9.2.4**) communicate at 9600 baud.

It is essential that the AT commands sent to the ESP8266 are terminated

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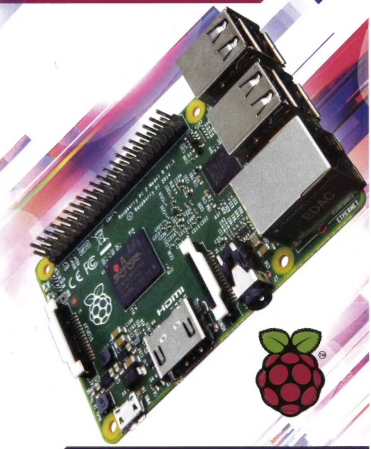

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Mailbag: continued

Errors in Spark Energy article

I noticed the following errors in the February 2015 issue of SILICON CHIP.

(1) On page 48, in the righthand column in the section "Estimating Spark Energy", there is a sentence which says "So for this example a -30mA peak spark current has an average spark current of about 15mA over a 2ms interval. The charge transferred across a 1000V load (the spark) is about 30mQ (millicoulombs) resulting in about 30mJ (millijoules) per spark."

The error is in the amount of charge. 30mA for 2ms is 60μC (microcoulombs) not millicoulombs. However, the maths is correct in the following paragraph.

(2) Page 62 in the section titled "Calibrator circuit"" reference is made in the test to ". . . with a repetitive 2ms -5V pulse across the 150W 5W resistor.". It should of course read 150Ω 5W resistor.

(3) Page 59 bottom right corner: the text says "The inverting input, pin 3, normally sits . . .". The inverting input is pin 2 not pin 3.

I also wish to say that I thoroughly enjoy Leo Simpson's editorials. I don't always agree with them but I always find that they give me food for thought. I enjoy reading his thoughts on the wide variety of subjects he covers. Keep it up, please.

David Williams,
Hornsby, NSW.

Comment: these errors have now been fixed in the online edition.

with CR+LF. My installation of Tera Term defaults to Newline=CR. This must be changed to Newline=CR+LF for transmit in Setup->Terminal.

Greg Donnan,
Anakie, Vic.

Mains Moderator saves power & protects appliances

Our line voltage here in Perth sits very close to 250VAC RMS, so I decided to build the Mains Moderator from the March 2011 issue. I also fitted the Soft Starter from the April 2012 issue down stream and a wireless GPO controller up stream, to power our LCD TV plus separate amplifier and DVD player.

I used the Appliance Energy Meter (SILICON CHIP, July & August 2004) to measure the power with and without the Mains Moderator and found a saving of 30W. This saving is all the time the TV is on. Of course, I expect the inverter life to be improved, as well.

Luckily, the TV memorises its status and channel, so when it is switched on with the remote power switch, up it comes and with no "bang" as all the capacitors in the TV and amplifier charge up softly. On switch off, the standby power is a little less than 2W. The PVR is permanently powered from a separate GPO, as it needs to wake itself up to begin scheduled recording. Ah – the wonders of technology!

Ian Thompson,
Duncraig, WA.

Deluxe GPS 1PPS Timebase interface adaptation

I used the Deluxe GPS 1PPS Timebase (SILICON CHIP, April 2013) project to provide the interface for a Trimble Resolution-T GPS module. This module runs off 3.3V, however as its output signal HIGH level is only about 2.85V, it is not compatible with the 40106B specified for IC1 which has a higher input threshold.

Substituting a 74HCT14 which has a lower threshold but still shares the same pin-outs fixed this issue. This may be of interest to others contemplating the use of 3.3V modules.

The Trimble module has a particularly stable 1PPS output with standard deviation jitter of less than 12ns and this makes it a good choice for feeding a frequency counter or a disciplined oscillator. Used modules sell for about US$25 on eBay (my unit had a build date of March 2013 and looked near new). Trimble provides excellent monitoring software which is freely available – see **www.trimble.com/timing/resolution-smt-GG.aspx** and click on VTS software.

To make full use of the many software features, forward control of the module is required. I used a simple NPN transistor circuit with a 10kΩ base resistor and the collector connected to the module's Rx input, with the pull-up resistor reduced from 10kΩ to 1kΩ. The base resistor then connects to pin 3 of the DB9F serial connector. As negative voltages can be present on pin 3 of the connector, I placed a protection diode between the base and emitter of the transistor.

Software features include a Google Earth view position map, satellite almanac and ephemeris data. The default data protocol is proprietary TPIS although the modules can be switched to NEMA. The module does require an external active antenna with an SMB female connector (US$7 on eBay).

The module draws about 110mA plus about another 10mA or so for the antenna. Hence a 1A LM3940 or similar regulator must be used for REG1 and the output capacitor increased from 10μF to 33μF.

Trevor Woods,
Albany, NZ.

Impact driver operation is more complex than may be thought

The dynamics of impact drivers are not as simple as some might have us believe. Alan Torrens' explanation on page 6 of the March 2015 issue is essentially correct. However, the dynamics are not that simple. For example, the force (torque) on the nut or bolt is far from constant and so in using the equation which expresses the Conservation of Momentum what is the torque on the nut or bolt?

Certainly, the torque exerted by the wrist on the wrench can reasonably be taken as a constant. In the case where the wrench makes good progress with each impact and the nut or bolt rotates quite a bit with each impact then using the Conservation of Momentum equations will give a good approximation. But the maximum torque rating of the device as quoted in the January question will not work with this equation.

A more complete explanation is as follows. In the first instance, one needs to focus on the fact there are three free bodies involved: (1) the body of the driver including the handler's hand, (2) the hammer inside the device and (3) the anvil which is struck by the hammer and which is connected in some way to whatever is being tightened.

The dynamics of an impact between two otherwise free bodies needs to be precisely stated. When two bodies strike one another, the forces, which each exerts on the other, are equal and opposite. However, it is very important to realise that in the case of an impact, the magnitude of the forces referred to here are rapidly changing with time. At any instant in time, the force that the first body exerts on the second body is equal in magnitude and opposite in direction to the force that the second body exerts on the first body, so called "equal and opposite", but that the magnitude of that force, is in general, rapidly changing.

It is misleading and wrong to refer to them as having a magnitude F. "F" is not a constant but must be defined as F(t), a time dependent quantity. In some simplified configurations, the magnitude of the forces resembles a sinewave; certainly never a constant F.

The device repeats a process which can be divided into three stages: (1) time t1, when the hammer is accelerated towards the anvil; (2) time t2, during which the hammer strikes the anvil (the first time, t1, might be 100 or more times longer than time t2); and (3) time t3, when the accelerated anvil exerts a force on the nut or bolt via the relatively elastic connections involving the socket etc.

During period t1, when the free body, which is the body of the device and handler's hand, exerts a force on the hammer, which is inside the device, the magnitude of that force might

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Mailbag: continued

reasonably be taken as a constant, say F1.

During period t2, the free body, which is the hammer, exerts a force on the free body which is the anvil, the dynamics of which are relatively complicated. The interaction depends on the shape and elasticity of the anvil and hammer. If the two bodies were in fact two rigid bodies and they met each other at the ends of an elastic spring, then the motions would be described as a sinewave starting at zero angle at first impact and ending when the angle is equal to PIE when they separate: half a sinewave.

Note that there is no single value involved. However, an impact wrench is most effective if the impact is as short as possible and it is desirable to eliminate as far as possible any spring between the hammer and the anvil. What happens can best be visualised by thinking of two jellies hitting one another. All sorts of vibrations are set up. These can be calculated and are the Eigen Functions but suffice it is say that t2 is very much shorter than t1.

During period t3, measured also from the start of the impact, the free body which is the anvil winds up the shaft connecting the anvil to the nut or bolt. It is desirable for this connection to be as rigid as possible. During t3, the torque in the connecting shaft between the anvil and the nut or bolt can reasonably be described as a portion of a sinewave up to the moment when the torque exceeds the friction in the threads etc, when the torque will remain relatively constant during the time when sliding occurs. The time t3 is longer than t2 but shorter than t1. The softer the connection between the anvil and the socket the less effective the impact wrench.

A non-critical observer might note that because there is a small torque exerted by the wrist for a long period of time and a large torque exerted on the nut or bolt for a short period of time, then these numbers seem as if they might fit into the equation stating the Conservation of Momentum. But the mechanics and dynamics are more complicated than this equation describes. One needs to note what the equation expressing the Conservation of Momentum purports to describe.

As stated above, when the wrench is making good progress tightening something, working well under its rated capacity, then for that situation alone, where the torque on the nut or bolt is constant at the sliding friction level for the time while the nut is moving, and because the wrist torque is also reasonably constant, then the equation expressing the Conservation of Momentum can be used correctly.

But for the situation where the wrench is developing its highest torque the torque on the nut or bolt will have a sinewave shape and the equation expressing the Conservation of Momentum does not apply. Maximum torque is highly dependent on the elasticity of the connection to the socket. Any extension shaft will greatly diminish the magnitude of the maximum tightening torque, as expressed in the January 2015 question on page 101.

Dr Kenneth E. Moxham,
Urrbrae, SA.

Recycling a cordless drill

I was interested in the letter from B. D., of Hope Valley SA in the "Ask SILICON CHIP" pages of the February 2015 edition and it has prompted me to record my own experience in this regard. I retrieved a cordless drill from a rubbish dump because apart from the fact that there was no battery in it, it appeared to be in reasonable condition. Also it was a Bosch brand and made in Switzerland.

The voltage rating was 14.4V, the same as a LiPo battery I had bought having read the article in SILICON CHIP about these batteries. I wired the battery to the drill using Anderson Powerpole connectors and was pleasantly surprised by the performance which was excellent – plenty of power and with the 4Ah battery, it goes for ages. The battery is attached to the base of the drill with cable ties and as the DC connectors are accessible, the battery can be recharged easily. It's new life for a good old drill.

Keith Gooley,
One Tree Hill, SA.

Wireless audio repeater for PA system

I recently had occasion to build a PA system for my club. One consideration I wanted was to feed the signal to the rear of the room wirelessly. The distance was about 15 metres and running cables to rear speakers was really not acceptable.

I spent a great deal of time and effort on systems like Bluetooth – unacceptable latency – FM transmitters and hours on the internet looking for suitable systems. In the end I hit on the idea of modifying a wireless microphone and it works really well. I just thought I'd pass it on to you and your readers should it be of interest.

Briefly, I used one of the dual BNK B701 microphones at $50 plus shipping off eBay (also used for the club's two wireless microphones). The board was removed from the microphone and a 3.5mm mono socket was substituted for the microphone. There was a 47kΩ resistor in series with the compander input so I raised that to 470kΩ and replaced the washer shaped antenna with a telescopic version. As the regulations only specify input power into the antenna it is still legal.

It was installed into a plastic box from Jaycar with a front LED replacing the internal microphone LED, an ON/OFF switch and a 9V battery compartment with external access.

It transmits from the front amplifier to the BK701 receiver, then to a $25.00 Lepai 2020A+ amplifier and then two stereo speakers, one each side at the rear of the room. I used a 15-metre 250VAC extension lead from Bunnings with the plug and socket cut off and a 0.25-inch mono plug to connect the second speaker.

I used an ALDI Livingston FA-30 I had lying around at the front which as well as the repeater also drives (by cable) a second Lepai 2020A+ which in turn drives two Pioneer car speakers in pods mounted one above the other, which I also had lying around.

I did find that the with the Lepais mounted on the side of the speakers, vibration caused the volume control to alter. I moved them and I have also successfully replaced one volume pot with a $15 20kΩ linear stepped attenuator from

Mailbag: continued

LED lighting can cause interference

LED lighting is very popular as it is efficient and the LEDs last a long time. I used to work in the predecessor to the ACMA as an interference investigator, hence I still get asked by people about the causes and cures of severe interference to television and radio reception that they may be experiencing. LEDs themselves do not cause interference but the power supplies to change the input supply voltage to that needed for the LEDs in many instances do.

I would suggest that current and potential users of LED lighting make sure that the lights do not cause interference. They should have a compliance sticker on them to indicate that all relevant EMC/EMI standards are met. However, I have found items with compliance stickers on them have created considerable interference (compliance labels are quite cheap!). Many of the interfering LED lights are sourced cheaply over the internet. I have made sure that all my LED lighting does not cause any interference.

Rodney Champness, Mooroopna, Vic.

eBay. At 220-230MHz, these wireless microphone transmitters go through walls very nicely – at least they did for me. I also tried converting a GT-TECH GT-02 wireless microphone but the quality is not so good.

Josh Stevenson. Moe, Vic.

Improvements to Poor Man's High-Voltage Probe

With respect to my high-voltage probe circuit, as featured on page 84 of the March 2015 issue, I found that in practice it was better to make the 4.7pF capacitor a 10pF variable type. This allowed me to adjust rise time for both (+) and (-) inputs independently to get optimum "no overshoot" rise times for each input. The nett effect was to get a very clean rise time for both single-ended and common mode responses and optimised high frequency CMRR (common mode rejection ratio).

In future, I may modify my unit to use ±15V external supplies, to allow ±1200V signals to be monitored. I have used it successfully to monitor voltages in a 240VAC CFL light power supply. The 1mV p-p output noise limits measurement to >100mV p-p at the input but adding a 100kHz low pass filter (10kΩ/150pF) to the output allows high-frequency noise to be suppressed so you can make measurements above 20mV p-p referred to the input.

If you are interested in <10kHz responses then the output filter could be reduced to 10kHz (10kΩ/1500pF).

Peter Kay, Dromana, Vic.

Suggestion for a CAN bus watchdog project

I have an automotive EFI engine that I would like to have monitored by a watchdog device, ie, an alarm/relay would operate when a monitored engine parameter is operating outside of a pre-programmed window (eg, coolant temperature or oil pressure). This is particularly useful for engine protection.

A project such as this would suit people who do not want to or can't be looking at their engine instruments regularly. It would especially suit engines that are fitted to vehicles that don't include an OEM CAN bus style instrument cluster, such as boats, race cars, kit cars, engine upgrades.

In particular, I have a requirement for an MIL (malfunction indicator light) for registration purposes. I have a kit car with a Ford Coyote engine installed. In its native application (Ford Mustang), the MIL light is part of the instrument cluster which receives its status via the CAN bus. As this instrument cluster is not used in my car, there is no simple way of driving a MIL. This

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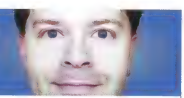

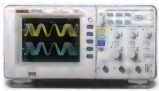

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Mailbag: continued

How to determine transformer winding voltages

I have just read Nicholas Vinen's article in Serviceman's Log pages of the February 2015 issue and I want to comment on his derivation of winding voltages. In the case of the input winding being open circuit and a good guess at the voltage of one of the secondary windings, the easier way is to feed a mains frequency voltage of say half the nominal voltage into the known winding and then measure the voltage on the remaining winding(s).

The ratio of these voltages will give the no-load voltage of the unknown winding. Also, if none of the winding voltages are known and a Variac is available, an estimate of the voltage can be obtained by monitoring the input current (the magnetising current) while increasing the voltage. The current will rise quite quickly just after the nominal voltage is reached due to magnetic saturation.

Sometimes it is possible to gain access to the thermal fuse and short it out. Of course, this removes the protection but it is no worse than the solution adopted in the article.

Charles Borger,
Croydon, Vic.

is a very common problem for people installing modern engines into vehicles with custom instrumentation.

I thought I would mention this idea for a project as I have not been able to find anything commercially available other than industrial engine controllers for generator sets and marine diesels. There are certainly plenty of people in the kit car, hot rod and race scenes that would make good use of such a project.

As said by many others before me, thank you for an excellent magazine, with a great technical balance.

Nigel Allen,
Magill, SA.

NBN connection at last

I finally bit the bullet and had the NBN connected. I went with TPG because they offered far and away the best deal ($79.95 per month with unlimited just about everything).

I cannot fault their service; everything went very smoothly and it all just works. Pulse dialling is not supported but everything else (fax, answering machine etc) works seamlessly. I can talk on my old phone and pick up calls with it but I have to dial out with a different phone.

Ironically, I picked up the very first call that came in with my 60-year-old phone and it was a man with a very strong Indian accent trying to tell me he was from Microsoft and that my computer has a virus in it!

The only minor snag was that even though Telstra had disconnected my service and ported my number to TPG, the phone line was still connected to something, so when I plugged a phone cable into the NBN box and plugged the other end into a phone point, I just got a horrible growling

noise. Anyway, I just snipped the wires where they enter my garage and that was that.

Which brings up an interesting point: since my internal phone wiring is now only connected to the outside world by a fibre-optic cable, I should be able to connect anything I like and modify the wiring any way I like.

Keith Walters,
Riverstone, NSW.

Climate change & technology

With regard to the Publisher's Letter in the February 2015 issue, I don't fully agree with your policy that peripheral electrical/electronic subjects should be covered in SILICON CHIP magazine. I don't buy it for that.

One aspect of Climate Change (about which I'm happy to be called a sceptic) that has an electronic/engineering dimension is how the temperature of the Earth (absolutely or relatively) can be meaningfully defined – to within a few degrees, let alone tenths or hundredths of degrees.

The definition has to include the atmosphere somehow or other I would think, not just the surface. And whether one averages daily maximum and minimum for a daily figure – and why. And how to average say seaside/sea-level Sydney with inland/altitude Canberra?

Assuming a definition can be agreed somehow, how can meaningful measurements be made to within tenths or hundredths of degrees, even at ground level, let alone altitude? And assuming all the above can be done, how can today's measurements be melded with historical numbers?

And finally, why are solutions to possible future problems only looked at in the context of today's technologies? SILICON CHIP readers, especially the older ones, have seen enormous technological changes contributing to improved quality of life for many if not most.

Surely it is at least equally appropriate to be optimistic, rather than pessimistic, about the future ingenuity of the human race in mitigating any problems, and coming up with brand new solutions and initiatives. This seems far more likely to me, as a retired engineer, compared with any problems which might flow from unlikely, small temperature rises in some places.

Mike Dinn,
Canberra, ACT.

Time domain reflectometry on the railways

With respect to the articles on Time Domain Reflectometry in the November & December 2014 issues and a subsequent letter in the Mailbag pages, you may find this of interest.

Many years ago I was told that VicRail used a TDR to find the location where a train overhead power line had come down. From memory this is how it worked: I was told that they had an overlay that they would put over the TDR screen. The overlay showed what the trace should look like if the power line was OK. The point where the measured TDR trace was different would show where the power line was down.

Also marked on the overlay were the locations of road crossings and buildings. The point where the traces were different with reference to road crossings etc indicated

Finally! Here's a fully featured Arduino Shield that not only solves the stacking problem but also uses robust 240VAC connectors to control mains devices. The BCS Mega-Shield is the one Shield that will enable you to control real-world high-powered industrial systems.

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where to look and fix the overhead power line – an interesting application where reflections are normally there when the line is OK. The fault location is where the reflection is not as expected.

It would be interesting to know if they still use this method today.

Roderick Wall,
Dandenong, Vic.

Vintage radios should be kept original

In recent years we have come to realise that not all old equipment be it cars, motorcycles, trucks, military weapons and radio sets should be fully "restored" to what the restorer imagines to be new condition.

To illustrate, I recently visited the Portland Power Museum and among their beautifully restored motorcycles is an ancient machine in poor condition with side car that proudly boasts the sign, "Do not clean me – I am meant to look like this". The machine is the classic "barn find" and is original in every way, including the patina caused by years of use and abuse. Interestingly, this exhibit drew much favourable comment from visitors.

Don't get me wrong – there is a place for restoration but just as importantly, we should sometimes conserve items that come our way so that future generations can see the originals without our early 21st century makeover. And that is why I was horrified when reading the Vintage Radio pages in the March 2015 edition which described the "restoration" of a Tela-Verta 1948 Musiclock Model 204C Mantel Radio. The source of my horror was the caption: "Left: the clock mechanism (to the left of the tuning gang) was in a poor state and was replaced by a modern quartz clock movement".

Instantly the value of the restored radio in a historical sense has been destroyed. Also, I venture that the value to astute vintage radio collectors would be far less than if the inoperable clock was left in the radio. If the clock has to run, I venture that most electronics enthusiasts can run a lathe or mill to make replacement parts. After all, these machine tools are far easier to use than a modern oscilloscope.

So, may I recommend to those bent on restoring old electronic equipment that they consider the conservation approach occasionally. Leave the marks and dings in the cabinet and the yellowed dials – these are the ghosts of our grandparents sitting in smoky lounge rooms listening to John Curtin say those famous words: "Every Australian should consider himself at the service of the government – whether he likes it or not".

Gerard Dean,
Glen Iris, Vic. SC

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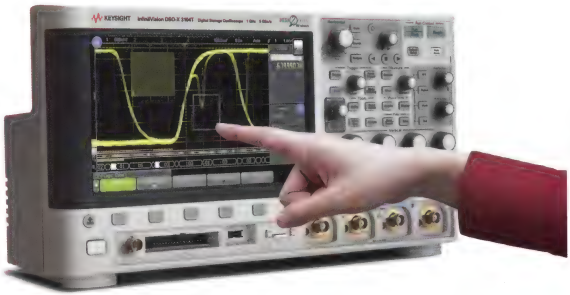

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Helping to keep the skies safe . . .

by Dr David Maddison

Airborne Weather Radar

Airborne Weather Radar enables flight routing to avoid extreme weather in order to keep passengers and crew safe and more comfortable – and to avoid damage to the aircraft. Huge advances have been made in this technology in recent years, including Rockwell Collins new "MultiScan" ThreatTrack Radar, released only last year at the Singapore Airshow.

Despite the fact that flying is the safest way to travel, the year 2014 was perceived by many as a bad year for aviation – although that really depends upon how you analyse the statistics.

According to the Geneva-based Bureau of Aircraft Accidents Archives (BAAA) there were 111 aircraft accidents in 2014, the lowest number of accidents since 1927. The BAAA counts any aircraft crash in which the aircraft is certified for at least six people plus the crew. It also counts shoot-downs but does not count military aircraft except troop carriers and other aircraft that can carry more than six passengers.

Deaths are a different matter, however and 2014 saw 1,328 people die in aircraft crashes and shoot-downs, the most since 2005, according to BAAA statistical methods.

Cause	1950s	1960s	1970s	1980s	1990s	2000s	Average
Pilot Error	42	36	25	29	29	34	32
Pilot Error weather related	10	18	14	16	21	18	16
Pilot Error mechanical related	6	9	5	2	5	5	5
Total Pilot Error	58	63	44	57	55	57	53
Other Human Error	3	8	9	5	8	6	6
Weather	16	9	14	14	8	6	12
Mechanical Failure	21	19	20	21	18	22	20
Sabotage	3	5	11	12	10	9	8
Other Cause	0	2	2	1	1	0	1

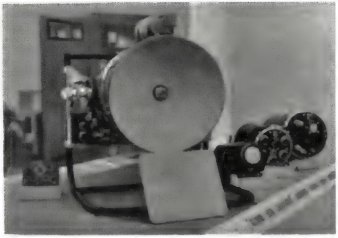
Fatal accident causes for commercial aircraft with 19 or more passengers on board from 1950 to 2010. Over that period weather-related fatalities, both involving and not involving weather-related pilot error have been a factor in 28% of accidents. (www.planecrashinfo.com/cause.htm).

However, according to the Aviation Safety Network (which counts only civilian planes which are certified for 14 passengers or more and does *not* count corporate jets, shoot-downs or sabotage) in 2014 there were 692 people killed in aircraft incidents making it the safest year since 1945. This would obviously exclude the 298 killed when Malaysian Airlines flight MH17 was shot down over the Ukraine.

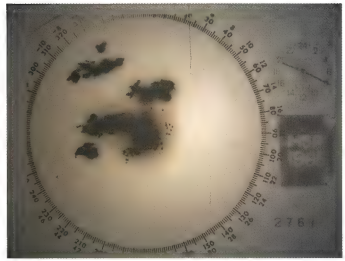
According to the BAAA there were 163 weather-related fatalities in 2014 and 162 of those were on Air Asia flight QZ8501 that crashed into the Java Sea off Indonesia. The aircraft was an Airbus 320-200. Historically, weather-related aircraft fatalities due to crashes are a factor in 28% of cases.

Avoiding weather of sufficient severity to put an aircraft

Adverse weather effect on an aircraft: a lightning strike.



World's first airborne weather radar – the ECKO airborne "cloud and collision warning search radar" from 1950.



The first weather radar image of a "hook echo" which is associated with tornadoes, taken in 1953.

at risk is of particular importance. Planning to avoid potentially dangerous weather starts at the flight planning stage but after take-off weather continues to be monitored both from reports radioed to the aircraft and on-board weather monitoring systems, the most important of which are the pilot's Mark I eyeballs!

Some aircraft operating in some areas also transmit weather data to meteorological authorities where it is fed into weather models to supplement data from weather balloons and other sensors.

Apart from the possibility of severe weather causing fatal aircraft crashes, a much more common occurrence is injury to passengers and damage to aircraft caused by turbulence.

In order to assist aircraft operators avoid bad weather once in flight they use aircraft mounted weather radar systems (radar is an acronym for RAdio Detection And Ranging).

Airborne weather radar detects bad weather in the aircraft's flight path and allows the pilot(s) to avoid the worst of it.

Another primary purpose of airborne weather radar is to ensure that course deviations to avoid bad weather are kept to the minimum that is necessary to avoid the adverse weather, without adding excessively to the distance to be flown which increases the time taken and adds to operating costs.

A problem?

The ability for radar to detect weather conditions was first noted during World War II where it was seen as a problem as radar returns from certain weather systems containing rain, snow and sleet could mask enemy activity. Ways were then developed to filter out such undesirable returns but scientists and engineers started studying the phenomenon after the war as a means to monitor weather and it has been extensively developed ever since.

The first airborne weather radar was from the UK company ECKO who, in 1950, developed the "cloud and collision warning search radar".

In later developments in 1953 a researcher with the Illinois State Water Survey produced the first radar image of a "hook echo", a particular type of weather radar signature associated with tornadoes. This demonstrated the viability of using radar to detect severe weather conditions and even provide early warning of developing severe conditions.

Early ground-based and airborne weather radars provided information on the reflectivity of whatever targets they illuminated but could give no information on the speed, of say, water droplets in a storm which would be indicative of wind speed.

Initial research on weather radar systems focused on observations of the precipitation within a weather system and its development, movement and structure, as well as making observations of the relationship between the characteristics of the radar echo and precipitation rate. When there was a greater precipitation rate there were more water droplets for the radar beam to reflect from and therefore the radar return was greater.

Doppler radar for weather

In 1950s research began on Doppler radar for weather applications although the earliest Doppler radar systems were developed during World War II.

The Doppler effect is the familiar property of a moving noise source such as a siren changing in frequency as it approaches an observer and then moves away. The same phenomenon applies to radar signals whose return echo is influenced by the velocity of the target they are bouncing off, such as rain drops.

Early Doppler radars used large and sensitive analog filters and were not practical for airborne operation except under special circumstances. It required the development

Feet, Nautical Miles & Flight Levels

While Australia (and indeed most countries) have adopted the metric system, in aviation Imperial units are still used: heights are generally expressed in feet, distances in nautical miles and speed in knots (which is of course nautical miles per hour).

You may also come across the term "flight level" with values between zero and perhaps 500. While a flight level strictly speaking is a barometric pressure (based on an international standard air pressure at sea level), it is conveniently used to express a height above sea level expressed in thousands of feet. Therefore an aircraft said to be flying at flight level 360 means it is 36,000 feet above sea level.

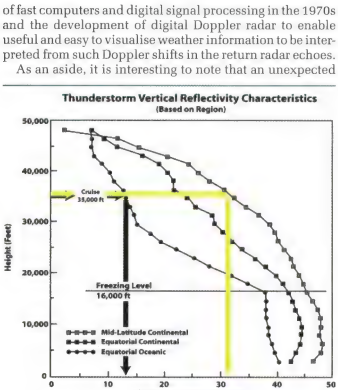
A primary threat to en-route weather avoidance is the fact that thunderstorm cell tops are non-reflective because they contain ice – a poor radar reflector.

of fast computers and digital signal processing in the 1970s and the development of digital Doppler radar to enable useful and easy to visualise weather information to be interpreted from such Doppler shifts in the return radar echoes.

As an aside, it is interesting to note that an unexpected problem during the development of early radar systems was that the Doppler shift induced by the reflection of a radar pulse from a fast moving object effected a phase shift in the returning signal, causing the signal to be cancelled and thus reverse phase-shift compensation had to be built into the radar set.

The development of Doppler radar enabled not only the shape and location of a weather pattern to be determined but also the velocity of precipitation within that weather pattern, and by inference, wind speed. Doppler radar also allows the elimination of returns travelling at a particular velocity. For example, with airborne radar, ground returns can be eliminated.

Airborne weather radar can be classified as either the more conventional and familiar two dimensional radar, or the more recently developed three dimensional radar. It might also come as a surprise to some that modern commercial aircraft do not have general purpose radars that indicate the presence of other aircraft or terrain. Avoidance of these is effected by pilot observation, flight planning, transponders on aircraft and automated aircraft systems.



Representative values of radar reflectivity as a function of height for equatorial oceanic and continental geographical areas and mid-latitude areas. For a given cruise altitude of 35,000 feet note the very large variation of reflectivity between the equatorial oceanic (black vertical bar) regions and the mid-latitude continental (yellow vertical bar) regions, corresponding to almost a 20dB range or 100 times power ratio. Note also the dramatic loss of radar reflectivity above the typical altitude for freezing of water at 16,000 feet. dBZ is a a logarithmic measure used for radar systems representing the radar echo intensity. (Diagram courtesy Rockwell Collins.)

What you see is not what you get!

Monitoring weather systems with radar might seem straightforward but there are many complicating factors. For a start, what is visible to the naked eye may not be visible to radar. For example, the cloud tops of thunderstorms contain mainly ice and that is a very poor radar reflector.

Typically, above 16,000 feet the temperature will be below zero centigrade and so water will be in the frozen state. The cloud top will be visible to the naked eye but not to the radar, or there will be very poor radar visibility so the flight crew have to correlate in their mind what they see with their eyes and how that relates to the radar information being received.

As a general rule, the lower two thirds of a cloud are visible to radar and the top one third is invisible, due to the presence of non-radar-reflective ice crystals. Of course, even though the cloud top may be invisible to radar it does not mean it is not of concern and there can be turbulence within that area of the cloud which can affect flight operations.

The presence of certain weather patterns that are visible to the radar below 16,000 feet can be used to infer that there will be certain formations above them and what their properties may be. This important point will be discussed later.

By convention, a display for weather radar is coded by three different colours according to precipitation activity. Green or Level 1 refers to light precipitation activity, little or no visibility and possible reduced turbulence; yellow or Level 2 corresponds to moderate precipitation, very low visibility, moderate turbulence and passenger discomfort; while red or Level 3 refers to heavy precipitation, possible thunderstorms, severe turbulence and the possibility of aircraft damage. Black corresponds to no return. A typical cloud will have heaviest precipitation at the bottom, with less higher up in the cloud.

It should be noted that the radar reflectivity varies enormously for different types of weather and is dependent on several factors. Mid-latitude continental thunderstorms have a much greater radar reflectivity than, say, equatorial oceanic thunderstorm clouds. This has lead to problems in the past as a weather radar might be optimised for typical weather conditions in, say, the United States where it is

manufactured and where most of its planes fly (mid-latitude continental area) but it would not work so well for an Australian operator in areas where many of its planes fly (equatorial oceanic). In fact the variation in radar return from these two types of conditions may vary by a factor of 20dB or 100 times (see graph).

Some examples of the different radar characteristics of thunderstorms are as follows: continental land-based thunderstorms (eg, USA) typically have high moisture content at high altitude and are more radar reflective than other types.

Oceanic thunderstorms (eg, Bay of Bengal) have low radar reflectivity as their moisture is located at low altitudes and the cloud tops are invisible to radar. Mid-latitude land based thunderstorms (eg, Brazil) have an intermediate radar reflectivity between that of continental land-based thunderstorms and oceanic thunderstorms.

In addition to geographical variation in the radar reflectivity of storms, there is also a seasonal variation. An additional problem is how to determine the severity of a thunderstorm cell. They may look the same to the eye and on the radar but one might be much more risk for hail and lightning than the other. Thus it is clear that a weather radar should ideally take all these factors into account.

When monitoring weather patterns from aircraft it is important to get a complete view of meteorological activity. With conventional 2D airborne weather radar the image provided is in one field of view like a slice and so the flight crew have to manually tilt the radar beam up and down to get a full picture of the weather. There is a fairly significant flight crew workload associated with obtaining comprehensive weather information with 2D radar. For an instruction guide on the operation of a typical modern 2D airborne weather radar you may wish to see the video *"EJETS WEATHER RADAR OPERATION"* http://youtu.be/VusX-0V2zvU8

3D Radar

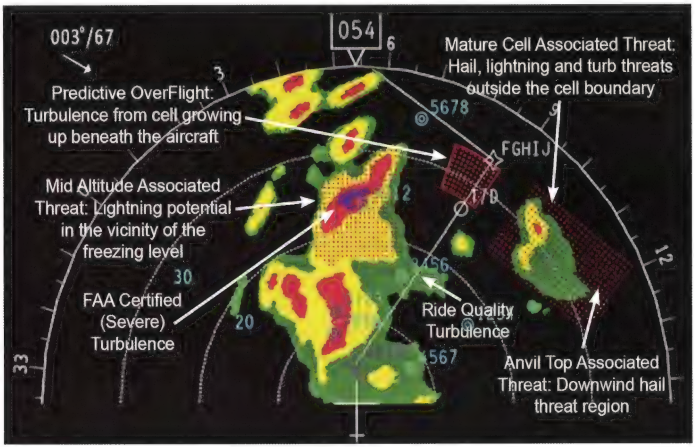
In recent times two companies have developed airborne 3D weather radar. One company is Honeywell with their IntuVue RDR-4000 system and the other company is Rockwell Collins with their WXR-2100 MultiScan ThreatTrack system. The objective with 3D radar is to reduce flight crew work load and to provide a more comprehensive picture of weather activity. This leads to greater safety and airline efficiency.

The Honeywell system is currently used on the Boeing 737NG, 777, C-17, and Airbus A380 aircraft and has been

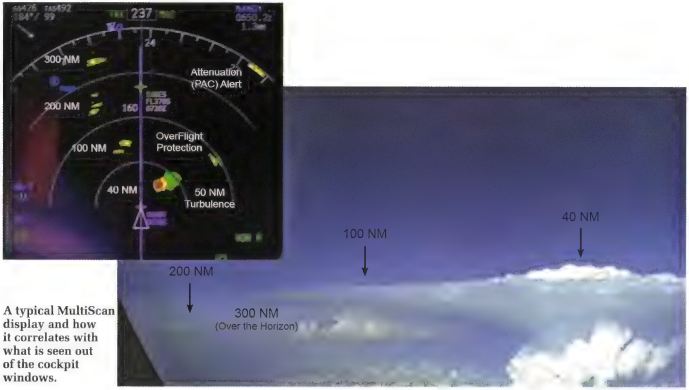
Ground-based weather radar

For those interested, there are numerous weather-related websites along with radar Apps for smart phones.

We featured the Australian Bureau of Meterology Doppler Weather Radar in the January 2010 issue (also see **www.bom.gov.au/australia/radar/** or **www.weatherzone.com.au/radar/**, among others).



A typical MultiScan radar display showing various weather threats.



A typical MultiScan display and how it correlates with what is seen out of the cockpit windows.

selected for the Airbus A350, Gulfstream G650 and KHI CX aircraft platforms.

Rockwell Collins system

The Rockwell Collins system has been installed on all Qantas aircraft, and is standard on all new Boeing 787 Dreamliners, Boeing 747-800s and Boeing Business Jets and is an option for the Airbus A320s, A330s and A340s, and Boeing 777s and Next-Generation 737s.

Qantas is a pioneering operator of the Rockwell Collins

Milestones in radar development

1865 James Clerk Maxwell publishes "A Dynamical Theory of the Electromagnetic Field" with the original four Maxwell's Equations which describe how electric and magnetic fields are generated and relate to each other.

1887 Starting in November of that year, Heinrich Rudolf Hertz discovers electromagnetic waves, proves Maxwell's Equations and publishes a series of papers, the first being "On Electromagnetic Effects Produced by Electrical Disturbances in Insulators".

1899 Guglielmo Marconi recalls his 1899 work in 1922 and says a "ship could radiate or project a divergent beam of these [electromagnetic] rays in any desired direction, which rays, if coming across a metallic object, such as another steamer or ship, would be reflected back to a receiver screened from the local transmitter on the sending ship, and thereby immediately reveal the presence and bearing of the other ship in fog or thick weather."

1900 Nikola Tesla in Century magazine wrote "by their [standing electromagnetic waves] use we may produce at will, from a sending station, an electrical effect in any particular region of the globe; [with which] we may determine the relative position or course of a moving object, such as a vessel at sea, the distance traversed by the same, or its speed."

1904 Christian Hülsmeyer demonstrates detection of a ship at a distance with his "Telemobiloskop" and is sometimes credited with the invention of radar but it does not give the range of an object direct. It is the first patented device that can detect objects at a distance.

1917 Lucien Lévy invents the superheterodyne receiver.

1921 The magnetron is invented by Albert Wallace Hull.

1922 US Naval Research Laboratory engineers Albert H. Taylor and Leo C. Young detect a wooden ship in the Potomac River by accident when conducting communications experiments and later in 1937 develop a practical ship-based radar.

1930 Lawrence A. Hyland at US Naval Research Laboratory demonstrates the reflection of radio waves from an aircraft.

1936 The development of the klystron at General Electric by George F. Metcalf and William C. Hahn (the invention has also been attributed to the brothers Russell and Sigurd Varian of Stanford University in 1937).

From this time on radar was rapidly developed, especially as the Second World War loomed and was soon started.

For more details on the history of radar you may wish to look at http://en.wikipedia.org/wiki/History_of_radar Some YouTube videos of interest are:

"Radar: Technical Principles: Mechanics" pt1-2 1946 US Army Training Film" http://youtu.be/64LUeQ4DAqg and *"Heroes and Weapons of WWII : 01. The Men Who Invented Radar"* http://youtu.be/5x37BVCvFRk

Rockwell Collins WXR-2100 as installed in aircraft cockpit and displayed on the central monitor.

system and has been using it since it was first released to the market in its original version in 2002. In fact, Qantas played a major role in its development. Qantas flies across the Pacific Ocean frequently, often at night and thus had a particular incentive to want better weather radar than conventional 2D weather radar which requires a lot of flight crew interpretation and represents a high work load.

While both Honeywell and Rockwell Collins make superb radar systems, the Rockwell Collins system has an Australian connection and it is the focus of the remainder

Air Turbulence

In Australia, there are about 25 in-flight turbulence related injuries every year according to the Australian Transport Safety Bureau (ATSB) with many more unreported. Some injuries are serious with broken bones and head injuries. In a typical severe turbulence event, 99 percent of passengers will not be injured.

Since Australia has some of the best flying conditions in the world, it is expected that flights outside of Australia will encounter more serious problems than flights within Australia.

From 2009 to 2013 there were 677 turbulence related instances reported to the ATSB on flights to and from Australia with 197 minor injuries and 2 major injuries.

Australia's Civil Aviation Safety Authority (CASA) classifies several types of turbulence and their causes as follows.

Types of turbulence

Light turbulence - briefly causes slight, erratic changes in altitude and/or attitude.

Light chop - slight, rapid and somewhat rhythmic bumpiness without noticeable changes in altitude or attitude.

Moderate turbulence - similar to light turbulence, but greater intensity. Changes in altitude/attitude occur. Aircraft remains in control at all times. Variations in indicated air speed.

Moderate chop - similar to light chop, but greater intensity. Rapid bumps or jolts without obvious changes in altitude or attitude.

Severe turbulence - large, abrupt changes in altitude/attitude. Large variation in indicated airspeed. Aircraft may be temporarily out of control.

Extreme turbulence - aircraft is violently tossed about and is impossible to control; may cause structural damage.

The causes

Thermals - Heat from the sun makes warm air masses rise and cold ones sink.

Jet streams - Fast, high-altitude air currents shift, disturbing the air nearby.

Mountains - Air passes over mountains and causes turbulence as it flows above the air on the other side.

Wake turbulence - Near the ground a passing plane or helicopter sets up small, chaotic air currents.

Microbursts - A storm or a passing aircraft stirs up a strong downdraft close to the ground.

Preventing injury from air turbulence

Occasional injuries are sustained by passengers due to air turbulence, mainly by being thrown about the cabin or by having items fall on them from open overhead lockers.

Almost all air turbulence related injuries can be avoided by ensuring objects are securely placed in overhead lockers and the lockers are kept closed and that seat belts are worn at all times, not just during take off and landing.

Also, crew instructions should be followed at all times and you should familiarise yourself with the safety information card in the seat back pocket.

Rockwell Collins MultiScan ThreatTrack Radar – features and development milestones

2002 Release of first model and it is put into immediate service by Qantas. This version was called MultiScan.

2003 On delivery flights of Qantas aircraft from the USA to Australia the flight time was used to test and develop the next version of the system. The aircraft flew with both a certified version of the radar and also the test unit. Data obtained were eventually incorporated into the 2008 model.

2006-2007 Rockwell Collins rented a Boeing business jet and flew around the world for three months to verify what was learned during the Qantas flights and this information was incorporated into the 2008 model.

2008 A major upgrade was made from the 2002 model. Storm top prediction was possible due to the addition of a geographic database of storm models in different areas at different times of the year. This was called MultiScan VI.

2014 Hail and lightning detection was added (predictive overflight). The ability to track 48 different thunderstorm cells and vertical analysis of thunderstorm cells were added. This version was called MultiScan ThreatTrak.

Note that the essence of the radar system is in its smart software, it represents a revolution in software rather than a revolution in hardware. Earlier model systems can be upgraded to the current specifications by software upgrades and some minor hardware changes in some cases.

of this article but the same general principles apply to the Honeywell system.

A video of the Honeywell IntuVue radar is available at *"IntuVue® 3-D Weather Radar"* http://youtu.be/w8IYyFm-JcF0 and a training video for its use *"RDR-4000 IntuVue™ Weather Radar Pilot Training for Boeing Aircraft | Avionics | Honeywell Aviation"* http://youtu.be/WNVtJeccNSM

A video of the MultiScan radar can be seen on YouTube at *"MultiScan ThreatTrack weather radar -- The worst weather is the one you can't see coming"* http://youtu.be/zJDduGPvOEA and Boeing crew training videos can be seen at *"MultiScan Weather Radar Module 1 Boeing"* http://youtu.be/EUjxFVRTdtw and *"MultiScan Weather Radar Module 2"* http://youtu.be/Ai_P-MwlrOw.

The Rockwell Collins MultiScan ThreatTrack has the following technologies:

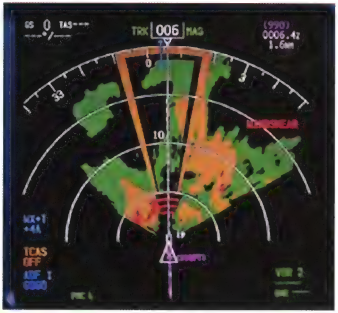
Geographic Weather Correlation: Recall from earlier in this article that there is significant regional variation in the radar reflectivity of thunderstorm cells as well as variation according to the time of year. This is a relatively recent discovery that occurred from 1997 onwards after the launch of the TRMM satellite (Tropical Rain Forest Measuring Mission).

This satellite has amassed a vast database of thunderstorm reflectivity information which, along with the work of leading climatologist Dr Ed Zipser, has enabled Rockwell Collins to embed thunderstorm models into the radar which are specific to particular geographic locations and time of year.

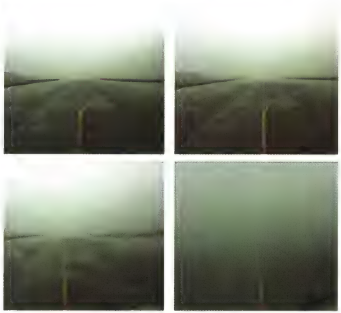
As previously noted, the tops of storm clouds are invisible to radar but the radar model is able to make predictions of the altitude of the true top of the storm cell and its level of hazard by knowing the location and time of year.

Core Threat Analysis: The radar can track up to 48 thunderstorm cores at once and also predict their severity.

Automatic Temperature-Based Gain: As the outside air temperature decreases, the cloud tops become less radar reflective so this feature increases the radar energy used to



Windshear is a hazard pilots dread because in the vast majority of cases they receive no visual warning of the phenomenon. Here the red and black stripes represent the actual windshear location along with a warning reminder at upper right.



This particular windshear occurred during taxiing. In these pictures from the cockpit the windshear can be seen in the form of a line squall approaching the aircraft down the taxiway. The pilot delayed his takeoff for 30 minutes until the thunderstorm had passed the airport and took off safely.

illuminate the cloud, effectively decreasing the proportion of the cloud that is invisible to radar.

OverFlight Protection: Traditional manual operation of 2D weather radars involves pointing the radar beam at the lower radar reflective portion of storm clouds. As a matter of simple geometry, if no adjustment to the beam angle is made, as the aircraft approaches the cloud the beam moves higher and higher until it is in the non-reflective part of the cloud and the storm cell disappears from view. The overflight protection feature keeps the beam pointed 6,000 feet beneath the flight path to keep the reflective portion of the cloud in view.

Predictive OverFlight Protection: Storm cells can grow at up to 6,000 feet per minute and when this happens a "bubble" of turbulent air is pushed above the cloud top. This feature tracks the rate of growth of storm cells and warns if there is a fast-growing cell in the vicinity, which is to be avoided.

SmartScan: As an aircraft turns with traditional radar there is a black wedge indicated a lack of data in the direction of the turn. This feature ensures that data is immediately acquired in the direction of the turn.

Two Level Enhanced Turbulence: USA FAA regulations require turbulence with a ±0.3G RMS severity to be displayed on weather radars but in addition to displaying that, areas with a less severe but still uncomfortable level of turbulence are also displayed.

Flight Path Hazard Assessment: The radar system looks for different hazards according to those relevant to the phase of flight.

For example during take off and landing the main concern is storm cells with convective activity and the Core Threat Analysis feature is used to evaluate the threat; during cruise the main threat is accidental penetration of thunderstorm cloud tops, so the Geographic Weather Correlation, Automatic Temperature Based Gain and the Predictive Overflight Protection features are invoked to prevent flying through the cloud tops.

In addition to these features there is also a wind-shear alert and an attenuation alert to warn when a storm cloud has absorbed so much radar energy that nothing behind it will be visible (radar shadow).

Quiet, dark cockpit

In keeping with modern aircraft flight philosophy of minimising the pilot workload (the "quiet, dark cockpit") the MultiScan radar ensures that only relevant information is displayed. Threatening weather can be detected out to a maximum range of 320 nautical miles while non-threatening weather 6,000 feet beneath the aircraft is not displayed.

In order to minimise the display of unnecessary information ground clutter is removed by the use of a global terrain model so that returns from the ground can be ignored.

With so many aircraft flying around the world, many fitted with the same model of radar, one might wonder if there is potential for the radars to interfere with each other.

This is not a problem as each radar pulse is sent out with a slightly different frequency and the radar will reject any pulse it receives that is not at the frequency that was sent out.

The radar dish for this system is around 70cm in diameter and sweeps side to side and up and down every four seconds.

Radar and the pulse repetition frequency and Doppler compromise

Traditional radar works by sending out a short signal pulse and then turning off the transmitter and listening for any signals reflected back to the radar antenna. Knowing that the radar signal travels at the speed of light, it is possible to determine the distance to an object, by dividing the total time for the pulse to return by two.

The required length of the period between pulses has to be enough time for the signal to travel out from the radar set to the target object and return. A long period between pulses allows objects to be seen at a long distance compared to a short inter-pulse period which will only allow objects to be seen a short distance away.

A compromise short inter-pulse period, corresponding to a high pulse repetition frequency (PRF) allows a potential target to be illuminated with more radio energy. This makes an object easier to see than if illuminated with a low pulse repetition frequency. However, a low pulse repetition frequency is needed if distant objects are to be observed and they are illuminated with less radio energy due to a lower number of pulses.

In fact, the energy reflected from the target back to the transmitter is also subject to the inverse square law so the energy received back at the radar set has a fourth root dependence, not a square root dependence. A consequence of this is that to double the effective range of a radar system the power has to be increased by a factor of 16.

With Doppler radar there is a further compromise which is that there is an inverse relationship between the distance that the radar can see to and the velocity that can be measured. When the PRF is low a long distance can be measured but only a low range of velocities. When the PRF is high, a much higher range of velocities can be measured but the range is reduced.

A more recent development in radar, at least as far as commercial augmentation is concerned, is Frequency-Modulated Continuous Wave, or "Broadband" Radar, which unlike traditional radar doesn't use a high-energy pulse but is "always on". Contradictory though it may sound, FMCW radar uses a lot less energy, is a lot safer to operate close to and is particularly applicable to marine use (see the feature in November 2010 SILICON CHIP).

Conclusion

Great advances have been made in radar since it was first invented. The most recent advances are being made not so much in radar hardware but in the software used to interpret and make use of the radar data.

As applied to airborne weather-radar, recent developments in 3D radar which serve to both reduce pilot work load and greatly increase the analysis of weather systems and the possible threats posed will make our skies even safer than they are now. SC

VirtualBench is a computer-driven 2-channel 100MHz digital oscilloscope, 34-channel logic analyser, waveform generator, 3-output adjustable power supply and multimeter, all in one box. It can be driven wirelessly using an iPad or from a PC via USB. Importantly, it integrates with National Instruments' LabView software for automated measurement and testing.

VirtualBench 5-in-1

Following the trend of integrating test equipment into one unit, VirtualBench is an instrument which can be used to test and debug many projects all by itself.

As you can see from the photos, it's "headless", with no screen and virtually no controls. The interface is handled by a PC or tablet.

This has some significant advantages. For one, you aren't stuck with whatever size or resolution screen the manufacturer has decided to put on the device.

We've seen many multi-thousand-dollar test devices with screens that are inferior to today's bargain basement tablets! So this "bring your own screen" philosophy can work quite well.

On the other hand, if you forget to bring your tablet/laptop or its battery is flat, you're out of luck; VirtualBench is effectively tethered to a computer.

Physically, as the name should suggest, the VirtualBench is very convenient for bench-top use.

At 255mm wide, 190mm deep and 73mm high it doesn't take up a great deal of space. In fact, since it has a flat top, you can argue that it doesn't take up any space at all.

At the very least, you can stack similar-sized equipment on top. An iPad fits quite nicely.

All the connectors you need frequent access to are on the front. The power button and Wi-Fi power indicator are at upper left, with the IDC connector for the logic ribbon cable in the middle and the two BNC scope inputs, calibration terminals, waveform generator BNC output and external trigger input at upper right.

Along the bottom, from left-to-right are the digital I/O terminal block, DC power supply output terminal block and DMM insulated banana sockets.

Features

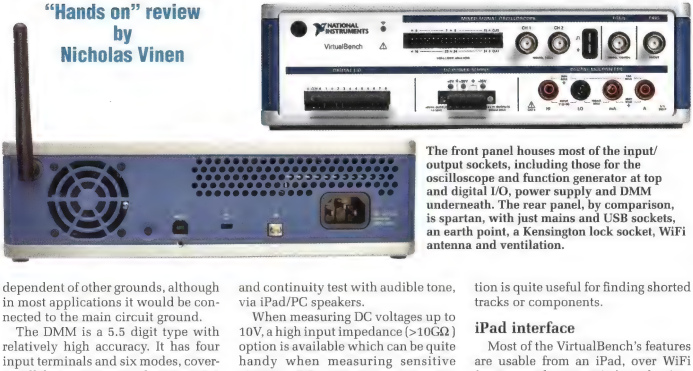
The digital I/O block provides a 3.3V power source (but only up to 20mA), ground connections and eight general purpose I/Os which can be used for controlling the equipment you are debugging or testing (more on that later).

The power supply outputs are 0-6V at up to 1A, 0-25V at up to 0.5A and 0 to -25V at up to 0.5A. Each can be set independently in 1mV steps and a current limit can also be set for each output.

So between these three adjustable outputs and the (fairly limited) fixed 3.3V, you can power a large range of devices from the VirtualBench without resorting to an external power supply.

Interestingly, the ground terminal for the ±25V adjustable supply is in-

"Hands on" review by Nicholas Vinen



The front panel houses most of the input/output sockets, including those for the oscilloscope and function generator at top and digital I/O, power supply and DMM underneath. The rear panel, by comparison, is spartan, with just mains and USB sockets, an earth point, a Kensington lock socket, WiFi antenna and ventilation.

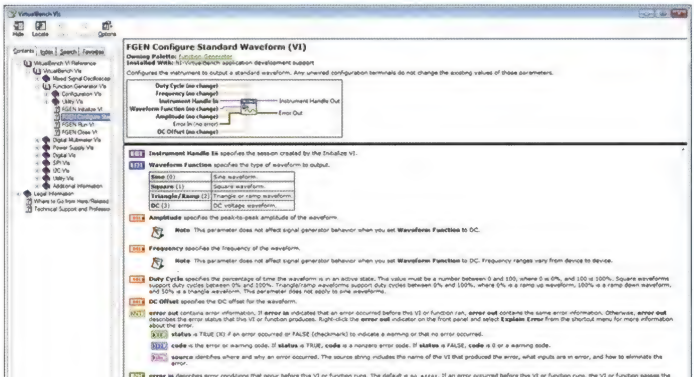
dependent of other grounds, although in most applications it would be connected to the main circuit ground.

The DMM is a 5.5 digit type with relatively high accuracy. It has four input terminals and six modes, covering all the most common functions: DC or AC voltage (true RMS, up to 300V DC/265V RMS), DC or AC current (up to 10A), resistance (up to 100MΩ), diode test (forward voltage up to 2V) and continuity test with audible tone, via iPad/PC speakers.

When measuring DC voltages up to 10V, a high input impedance (>10GΩ) option is available which can be quite handy when measuring sensitive circuits. DC current measurement resolution goes down to 0.1μA while resistance measurement resolution is down to 1mΩ; however there is no 4-wire test mode. Still, such resolution is quite useful for finding shorted tracks or components.

iPad interface

Most of the VirtualBench's features are usable from an iPad, over WiFi (see screenshot opposite). At the time of writing this review, there is no Android support but this is expected relatively soon; presumably, before the end of 2015.



When controlling the VirtualBench from LabView, many options are available. Fortunately, the built-in help explains them in detail. This screen shot shows the details for setting up the waveform generator.

The VirtualBench PC interface allows control over all the MSO, DMM, power supply and signal generator features. There are many digital channels so several serial buses can be monitored.

The interface is not difficult to figure out. The scope traces are displayed in the middle of the screen and can be moved around by dragging. Vertical scaling and the timebase can similarly be adjusted using two-finger gestures. The other displays and controls are above and below the scope traces, including the DMM features, scope measurements, power supply controls and function generator.

What we couldn't find in the iPad interface are the serial bus decoding options (which are present on the equivalent PC software) or controls for the eight-pin digital I/O bus on the front panel of the VirtualBench.

Presumably these more advanced features have been left out because they wanted to keep the iPad app simple.

Like a lot of WiFi peripherals, rather than joining your network, the VirtualBench requires that you connect your iPad to its WiFi network (ie, it acts as an access point).

The annoying aspect of this is that this means you lose Internet access while using it, so if you want to say download a data sheet during a debugging session, you will have to disconnect from the VirtualBench's WiFi and then reconnect to it again later.

It also means that each time you turn the VirtualBench on, you have to remember to re-join its WiFi network before running the app or it won't work. That's because the iPad will automatically re-connect to your normal WiFi network when the VirtualBench access point disappears.

As we said, this is a pretty typical way to interface with a device using WiFi and it does avoid the need to program your SSID and WEP password into the device but in the long run that would probably be a more satisfying solution.

PC interface

You have two options for using the VirtualBench on a PC. First there is the dedicated interface software which works similarly to the iPad software but with the extra features mentioned that are missing in the iPad version, such as the serial protocol decoding (SPI/I^{2}C/Parallel); see the screenshot above.

We found this software particularly easy to use.

For example, the menu for setting up serial decoding appears next to the button to turn the digital channels on and off when you move your mouse near it, and similarly other set-up menus appear next to related buttons.

The layout is visually clean and you really don't need a manual to figure the software out; most users will be up and running right away and will be able to figure all the functions out easily.

In some ways using a scope this way is very convenient because we often find when debugging a project that we refer to schematics, PCB overlays and software on a computer when trying to figure out what's going on.

Thus we often end up swapping constantly between the PC and a scope when troubleshooting a project.

In this case, the PC is the scope interface, avoiding the need to constantly switch between two different screens and sets of buttons. This also makes it easy to do things like save screen grabs to the computer.

All the basic functions work well. As a mixed signal scope, its performance is on a par with a typical, good quality 100MHz unit. Similarly, the DMM has reasonable accuracy if somewhat limited functions.

The power supply is convenient but with a maximum of 1A on its 0-6V output, won't necessarily cover all possible uses and so you may well require a separate power supply with a bit more grunt.

LabView integration

The other option for driving the VirtualBench from a PC is LabView and this unleashes the full power of the device. It allows you to create automated testing procedures and control them via a graphical programming interface.

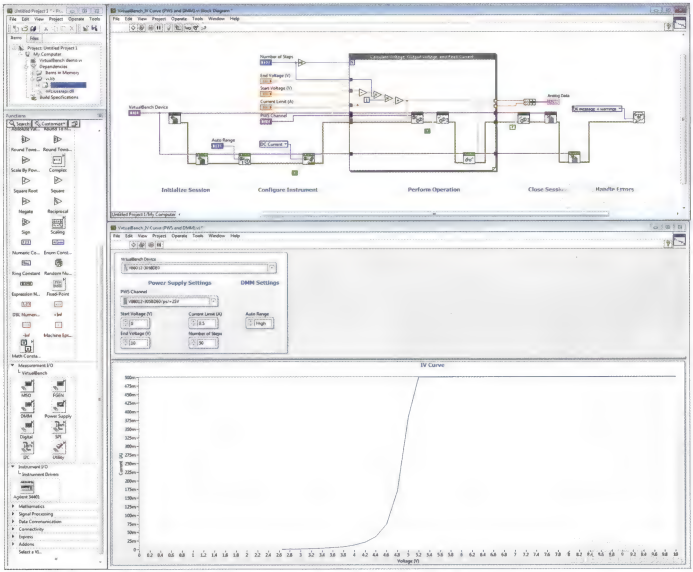
Automated testing is not only useful in a production environment, eg, for QA where you need to do a quick check that all the functions of a device are operating correctly before sending it out the door but also in a test, service and debug environment, such as the sort of development and testing work we do at SILICON CHIP.

For example, say you have a device which has a glitch after power up, if a certain sequence of buttons are pressed in a particular order. You're trying to eliminate this glitch by making changes to the software and/or hardware but each time you make a change, you need to check whether it has fixed the glitch or not.

You can design a test procedure in LabView which uses the VirtualBench to power up your device, wait for it to be ready, simulate button presses via its configurable digital I/Os, then run whatever tests are necessary using the MSO and DMM to verify correct operation.

The LabView software can then report whether the glitch is still present and if so, you can make further changes and try again. That makes such testing a lot easier and more repeatable and is especially handy if the glitch you're looking for is short-lived.

The image below shows the LabView software interfacing with our VirtualBench review unit. This is one of the example programs provided on the National Instruments website which uses the adjustable power supply and DMM features of the device to plot a



This demo program steps the power supply output through a range of voltages and uses the DMM to measure current and produce the plot at the bottom of the screen.

V/I curve for the device under test.

This sort of test works well because the adjustable power supply has such fine-grained control over output voltage.

The program itself is shown at top. This consists of a variety of blocks representing different parts of the VirtualBench device and different stages in the test, which are "wired up" together to determine a sequence of events. It is broken into five sections and the control sequence flows from left to right, with the five different steps labelled below.

The first step is initialisation and this involves the software connecting to the VirtualBench device and preparing the sections which are to be used (ie, power supply and DMM).

The configuration step sets the various test parameters such as what mode the DMM section will operate in (DC current in this case), the voltage range over which the power supply will be stepped and so on.

Parameters such as the voltage range and number of steps are set by the user in the "Front Panel" interface in the middle of the screen.

This makes it easy to adjust the parameters and run a new test without having to change the block diagram. The selected values are automatically fed by the software into the orange and blue rectangles in the block diagram which then feed into the control process.

The grey box outlined in the middle, above "Perform Operation" is a "for loop" which performs a set of tasks a fixed number of times.

In this case, it's used to step the power supply through the test voltage range and read the current level from the DMM each time. The voltage and current figures are then fed to the X/Y plot in the bottom pane via the pink "Analog Data" item at right.

The remainder of the items in the top pane deal with shutting the VirtualBench down once all the data has been acquired and telling the user whether there were any problems during the test (eg, if the multimeter input range was exceeded).

At left of the display is the "palette" with some of the blocks that you can place in the block diagram at top in order to perform different functions.

For this test, we connected a 3.9V zener diode across the power supply terminals and the plot at bottom shows its soft knee characteristic over the 0-10V test range and 0-500mA capability of the adjustable +25V power supply output.

Ease of use

LabView can seem daunting at first even for an experienced computer programmer, partly because of the large number of built-in functions but mostly because its graphical nature is quite different from the more common text-based programming systems.

However with the aid of examples and a little experimentation, it doesn't take long to figure out the basics. We managed to build a test from scratch and get it working in less than half an hour.

The supplied examples help a lot. In addition to the one described above, others include creating Bode plots, frequency response plots and stimulus/response measurements using the signal generator and oscilloscope modules.

The built-in context-sensitive help is excellent, once you've figured out how to get to it – you need to right-click on one of the block objects using the correct selection tool and then choose "Help" and you'll get a clear explanation of how the block works – see the earlier screen grab.

If you have programming experience, you should become comfortable with LabView after using it for a short time but it is a complex piece of software and will certainly take some time to master. The advantage of this complexity is that it's very powerful once you get used to it.

We decided to see just how practical the combination of LabView and VirtualBench is and to do this, we wanted to set it up to perform a function that wasn't mentioned in the documentation and for which there are no examples.

We succeeded in setting up a real time distortion analyser with spectrum display and this only took about 30 minutes to figure out. It would have been much quicker if we had more experience with the software.

We set up the waveform generator to produce a sine wave and fed this to the scope input. Our distortion analysis software then reported 0.1% THD+N with the second harmonic at -65dB, third at -61dB and fourth at -72dB as sas read off the spectrum plot.

While this set-up would be no match for our Audio Precision system in terms of performance, that certainly demonstrates the unit's flexibility when teamed with the LabView software.

From what we can see, there are a lot of other analysis tasks which would be possible to perform using this sort of set-up.

Note though that to do this sort of advanced analysis, you need to buy the more expensive "Full" version of LabView rather than just the "Base" version.

For the list of differences, see this web page: **www.ni.com/labview/buy/**

Signal processing functions available in the "Full" version include waveform and signal generation and conditioning (useful in combination with the Arbitrary Waveform Generator VirtualBench function), waveform measurements, windowing, filtering, spectral analysis, transformations and PID control.

Conclusion

If you're a die-hard iPad user you may appreciate the WiFi connectivity functions of this unit but in our opinion, to get the full benefit, you really need to use LabView on a PC.

While LabView is available for Mac OSX, the VirtualBench driver appears to be Windows-only for the moment.

The way that the various functions of the VirtualBench are integrated, combined with the power of the LabView software is by far its best aspect.

And note that LabView will also integrate with other National Instruments products, including their large range of data acquisition and signal generator devices.

So if you like the idea of a PC-controlled all-in-one test instrument and are interested in taking advantage of the automated testing capabilities available in conjunction with the LabView software, VirtualBench could be for you.

Pricing & availability

The VirtualBench is available direct from National Instruments, PO Box 382, North Ryde, NSW 2113. It retails for $2987, including GST. LabView is $550 (incl. GST) for the Base version and $1100 for the full version.

For enquiries or to purchase, go to **www.ni.com/virtualbench/buy/** or call them on 1800 300 800. SC

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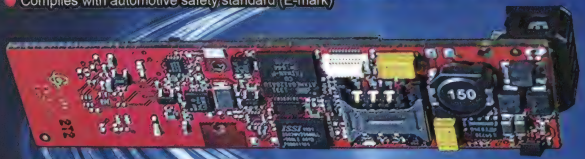

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Appliance Insulation Tester

By JOHN CLARKE

Do you think all your 230VAC-powered tools and appliances are safe because they are double-insulated? If so, you could be in for a rude shock – literally! Or do you think you are safe because your home (or workplace) is fitted with RCDs (Residual Current Devices)? Again, you could still be at risk of a severe electric shock. The only way to be reasonably sure about appliance and power tool safety is to test them regularly. That is where our Appliance Insulation Tester is a crucial tool.

LET'S BE BLUNT: an RCD will not save you from electric shock if you use a faulty power tool or appliance. Nor will it necessarily save you from death. Have we got your full attention now?

An RCD (commonly called a safety switch) will switch off the 230VAC power if it detects an imbalance between the Active and Neutral currents in the appliance circuit. That imbalance could mean that current is flowing through your body rather than the mains wiring. At least 30mA of current needs to flow through your body for a typical RCD to switch off the power – but depending on the fault, the current could be a lot more than 30mA and the time before it is switched off could be up to 150 milliseconds. That's long enough to experience a very nasty electric shock and one which could possibly kill you!

Well hopefully, it would not kill you but you could still be seriously injured. Say you get the shock while using the faulty tool and standing on an aluminium ladder. The shock could throw you off the ladder and you could be seriously injured or killed (again!).

And anyway, how you do know the RCDs in your home are working properly? Have they been tested recently?

You can now see that appliances and power tools should be tested regularly. So we have produced our Appliance Insulation Tester which checks whether the insulation resistance is adequate to protect you from serious shock on double-insulated or earthed appliances and power tools. It does this by applying 250V or 500V DC between mains Active and Neutral to the Earth on the 3-pin plug of earthed appliances (Class 1 appliance) or to

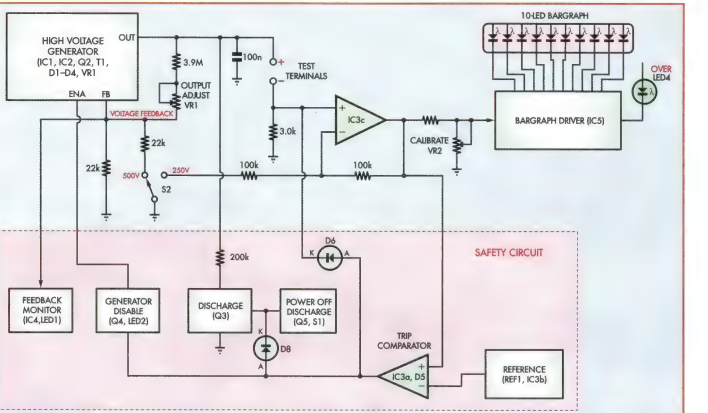


Fig.1: block diagram of the Appliance Insulation Tester. It uses a high-voltage generator (top, left) to produce either 250V or 500V DC which is applied to the test terminals. The resulting leakage current through the appliance under test and the associated 3kΩ resistor is monitored by op amp IC3c which then drives a 10-LED bargraph via IC5. IC3a monitors IC3c's output and shuts down the high-voltage generator via Mosfet Q4 if the voltage across the 3kΩ resistor exceeds 3V.

exposed metal on double insulated appliances (Class 2) and then the insulation resistance is measured. In general, an insulation resistance (IR) below 1MΩ is deemed unsafe.

There are a couple of appliances where this 1MΩ value does not apply. The first is with a portable RCD that has a functional earth (ie, requires an earth for correct operation) and the second is for appliances which have mineral insulated metal sheath heating elements. Check with the AS/NZS3760 standard for more information. Our Appliance Insulation Tester is not suitable for these devices.

Another instrument required

While our Appliance Insulation Tester will check most appliances, it does not apply 230VAC mains voltage and therefore cannot conduct an IR test on appliances that have a "soft" or a non-mechanical power switch such as in most appliances with remote controls (eg, DVD players and TV sets). These appliances can only be tested with an instrument that permits energising with the normal 230V supply voltage to measure the actual earth leakage current. We plan to feature an Appliance Earth Leakage Tester next month as a companion instrument.

Testing safely

We mentioned that the testing voltage used is 500V or 250V DC. 500V DC is the usual test voltage while 250V DC is used where an appliance has over-voltage protection. These voltages are high enough to give you a nasty shock if you come into contact with both the test probes, so we have incorporated three safety features.

The first is the use of shrouded banana sockets for the high voltage output terminals. Secondly, there is a 1mA (or 500μA depending on output voltage) trip current detector that shuts off the high voltage if this current is exceeded. So if you do make contact with both the test probes you will get an unpleasant "tickle" instead of possibly a more severe electric shock.

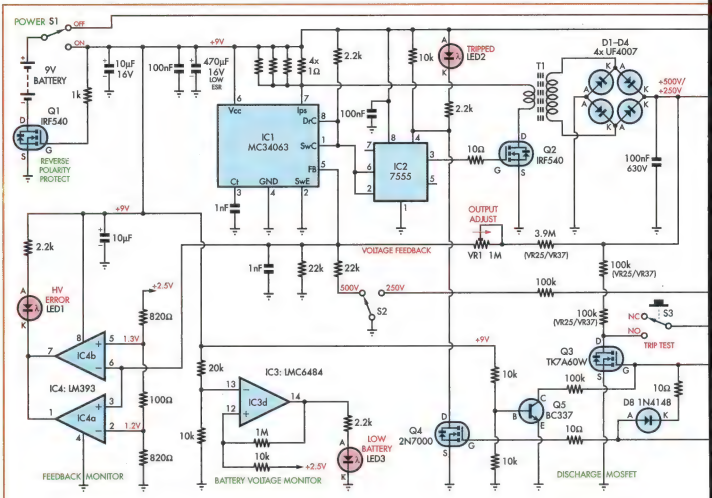
As well, the Tester has a Trip Test pushbutton which verifies that the unit will shut down if you make contact with the probes. It also lights a LED to indicate that it has been tripped. To restore operation, the unit has to be switched off and then on again.

Finally, a check LED is included to indicate if the high-voltage generator is not working correctly.

Simplified circuit

Fig.1 shows the simplified circuit arrangement of the Appliance Insulation Tester. It comprises a high-voltage generator that can be set to produce either 250V or 500V DC, with voltage feedback to maintain the required voltage with varying load. IC4 includes two comparators which detect if there is a fault in the high-voltage output. A high or low voltage is indicated with LED1 (HV Error).

The positive high voltage becomes the "+" test output while the negative (-) test output is connected to the supply ground via a 3kΩ resistance. When the test terminals are connected to an appliance to test for insulation resistance, any leakage current will flow through this 3kΩ resistance and so develop a voltage. This voltage is monitored by IC3c, a high input im-



APPLIANCE INSULATION TESTER

Fig.2: the circuit of the Appliance Insulation Tester. The high-voltage generator consists of an MC34063 DC-DC converter (IC1), a 7555 CMOS timer (IC2), Mosfet Q2, step-up transformer T1 and bridge rectifier D1-D4. IC3c monitors the leakage current through the two series 1.5kΩ resistors and drives IC5, while IC3a is the trip comparator for the safety circuit.

pedance, low input current op amp.

IC3c operates as a unity gain buffer for the 500V setting or with a gain of two when 250V is selected. So for example, a 1MΩ leakage resistance between the test terminals with a 500V DC test voltage would produce a current of 500µA. This gives 1.5V across the 3kΩ resistance and thus 1.5V at IC3c's output.

For 250V DC, the current with the same 1MΩ leakage resistance would give 250µA and there would be 750mV across the 3kΩ resistance. However, we still get 1.5V at IC3c's output because it now operates with a gain of two.

The pin 8 output of IC3c is attenuated and fed to IC5, an LM3915 dot/bar display driver (used in dot mode) and 10-LED bargraph display. The display shows resistance in 10 3dB steps: <707kΩ, 1MΩ, 1.4MΩ, 2MΩ, 2.8MΩ, 4MΩ, 5.6MΩ, 8MΩ, 11MΩ and 16MΩ. A separate LED lights for resistance values of more than 16MΩ.

Op amp IC3a compares the output of IC3c with a 2.5V reference voltage set by IC3b. If the voltage across the 3kΩ resistance reaches 3V, IC3a's output goes high to turn on Mosfet Q4 and disable the high-voltage generator. At the same time, Mosfet Q3 discharges the high-voltage generator's 100nF output capacitor via a 200kΩ resistance and the display will show a low ohm (<707kΩ) reading. In addition, LED2 indicates that the high-voltage generator has been disabled.

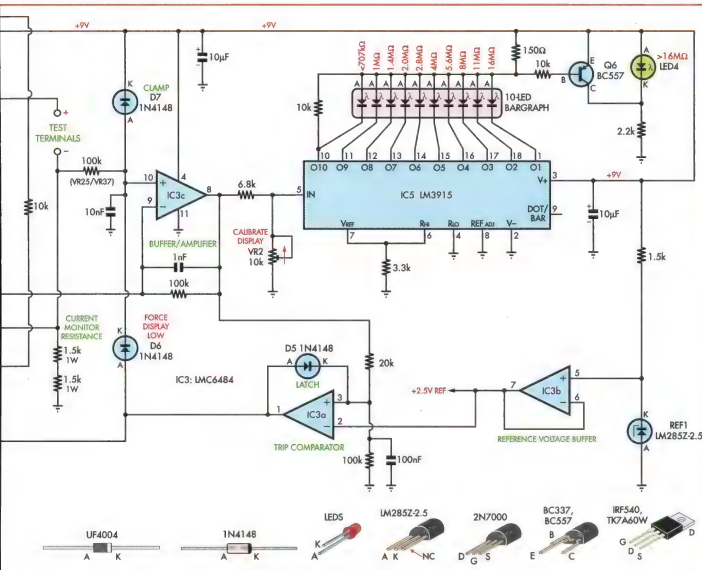
Finally, since the high-voltage output will be zero, the feedback monitor will turn on the high-voltage error indicator, LED1.

As already noted, to restore operation, the unit has to be switched off and then on again. Note that if the unit is switched off, Mosfet Q3 discharges the high-voltage capacitor, under the control of transistor Q5, which monitors the on/off switch.

Full circuit

The full circuit is shown in Fig.2. The high-voltage generator comprises an MC34063 DC-DC converter (IC1), a 7555 CMOS timer (IC2), Mosfet Q2 and transformer T1. If this circuit did not have the trip current protection feature, IC1 & IC2 could have been used in a slightly simpler configuration, with the 7555 used as a rail-to-rail Mosfet gate driver and with no gating function via Q4.

IC1c's oscillator runs at a nominal



30kHz, as set by the 1nF capacitor at pin 3. IC1's output pins (1&8) are open-collector transistors that are pulled up to the 9V supply by a 2.2kΩ resistor. The 30kHz output signal is coupled to IC2, a 7555 which is mainly used as an inverting buffer/gate which drives Mosfet Q2.

When Q2 is switched on, current flows through the primary winding of transformer T1 until it peaks at about 1.2A. This current flows through the four paralleled 1Ω resistors between pins 6 & 7 of IC1 and when it reaches 1.2A, IC1 stops its oscillator and Mosfet Q2 is switched off. Thus, the magnetic field in the transformer core collapses, producing high voltage in the primary winding. The secondary winding steps up the voltage and feeds a bridge rectifier comprising diodes D1-D4 to produce a 500V (or 250V) DC supply and this is filtered with a 100nF 630V DC capacitor.

Note that a single diode could have been used instead of the bridge rectifier. However, a single diode rectifier would require the transformer windings to be correctly phased and this can be problem for constructors winding their own transformers. Using

Main Features

- Displays insulation resistance in 10 steps from 707kΩ to 16MΩ with acceptable resistance in green and unacceptable resistance in orange and red
- 500V DC and 250V DC test voltages
- 1mA/500µA over-current trip for safety
- Over-current trip test and trip indicator
- Low battery indicator
- High voltage fault indicator
- High voltage discharges to safe levels at power off and over-current trip out
- Not suitable for portable residual current devices that incorporate a functional earth
- Not suitable for mineral insulated metal-sheathed heating elements

Appliance Insulation Tester: Parts List

1 double-sided PCB, code 04103151, 86 x 133mm
1 front panel PCB, code 04103152, 90 x 151mm
1 UB1 plastic utility box 158 x 95 x 53mm
1 ferrite pot core and bobbin set (Jaycar LF-1060 & LF-1062, Altronics L 5300 & L 5305) (T1)
1 pot core spacer eg 0.25mm cardboard 11mm OD or similar (see text)
1 9V battery clip lead
1 9V battery
1 9V battery U-shaped holder
1 20-pin wire wrap SIL socket strip for LED bargraph
2 SPDT toggle switches, PCB-mount (S1,S2) (Altronics S 1315)
1 SPDT pushbutton PCB-mount switch (S3) (Altronics S 1393)
1 red safety banana socket (Jaycar PS-0420)
1 black safety banana socket (Jaycar PS-0421)
1 shrouded safety multimeter test lead set (Altronics P 0404A, Jaycar WT-5325)
3 M3 tapped 9mm Nylon spacers
3 M3 tapped 6mm Nylon spacers
3 M3 x 12mm screws
3 M3 x 5mm screws
1 M3 x 10mm countersink screw
1 M3 x 25mm Nylon screw
8 M3 Nylon washers
2 M3 nuts
1 6.5m length of 0.25mm-dia. enamelled copper wire
1 700mm length of 0.5mm-dia. enamelled copper wire
1 40mm length of 230VAC rated red wire
1 40mm length of 230VAC rated black wire
3 PC stakes
1 1MΩ multiturn trimpot (VR1)
1 10kΩ multiturn trimpot (VR2)

Semiconductors

1 MC34063AP1 DC-DC converter (IC1)
1 7555 CMOS timer (IC2)
1 LMC6484AIN quad CMOS op amp (IC3)
1 LM393N dual comparator (IC4)
1 LM3915N dot/bar display driver (IC5)
1 10-LED green/yellow/red LED bar (Altronics Z 0964)
2 IRF540 100V 33A N Channel Mosfets (Q1,Q2)
1 600V low gate threshold N-channel Mosfet (Q3) (Toshiba TK7A60W or equivalent) (RS Components Cat. 799-5201)
1 2N7000 Mosfet (Q4)
1 BC337 NPN transistor (Q5)
1 BC557 PNP transistor (Q6)
1 LM285Z 2.5V reference (REF1)
4 UF4007 1000V 1A fast diodes (D1-D4)
4 1N4148 diodes (D5-D8)
3 3mm red high brightness LEDs (LED1-LED3)
1 3mm green high brightness LED (LED4)

Capacitors

1 470µF 16V low ESR electrolytic
4 10µF 16V PC electrolytic
3 100nF MKT polyester
1 100nF 630V metallised polyester
1 10nF MKT polyester
3 1nF MKT polyester

Resistors (0.25W, 1%)

1 3.9MΩ VR37/VR25 (3500V DC or 1600V DC)
1 1MΩ VR37/VR25 (for calibration) (3500V DC or 1600V DC)
3 100kΩ VR37/VR25 (3500V DC or 1600V DC)

1 1MΩ	1 1.5kΩ
4 100kΩ	2 1.5kΩ 1W
2 22kΩ	1 1kΩ
2 20kΩ	2 820Ω
8 10kΩ	1 150Ω
1 6.8kΩ	1 100Ω
1 3.3kΩ	3 10Ω
5 2.2kΩ	4 1Ω 5%

a bridge rectifier makes transformer winding and termination easier.

Since the load on the high-voltage supply can vary, we have voltage feedback to pin 5 of IC1 via a 3.9MΩ resistor and 100kΩ trimpot VR1, together with a 22kΩ resistor at pin 5 of IC1 to ground. VR1 is adjusted to provide an output of 250V DC. An extra 22kΩ resistor is switched via S2 to provide the 500V setting.

Either way, the feedback divider reduces the high voltage to a nominal 1.25V at pin 5 and this is compared against an internal 1.25V reference in IC1. If the output voltage drops, the duty cycle of the output waveform from pins 1 & 8 is increased to compensate (and vice versa).

Note that the 3.9MΩ feedback resistor is a VR37 or VR25 type, rated at 3500V DC or 1600V DC, respectively.

Note also that IC2 has its pin 4 reset pin connected to other parts of the circuitry. This is used to shut down the high voltage generation when required. Under normal operation, pin 4 is pulled high via a 10kΩ resistor to allow IC2 to operate.

Voltage fault indication

As mentioned above, the circuit has voltage fault indication and this comprises IC4, an LM393 configured as a "window" comparator. It drives LED1 when the voltage feedback signal fed to pin 5 of IC1 is outside the limits set at its pins 5 & 2 (of IC4). Normally, with feedback voltage in the range of 1.2-1.3V, the paralleled open-collector outputs of IC4 at pins 1 & 7 will remain high and LED1 will be unlit.

If the feedback voltage drops below 1.2V, pin 1 of IC4a will go low to light LED1. Similarly, if the feedback voltage goes above 1.3V, pin 7 of IC4b will go low instead to again turn on LED1. So if LED1 lights, it indicates that the DC-DC converter is not producing the correct high voltage.

It is not a completely foolproof check of output voltage because if one of the feedback resistors should fail or change its value, the feedback voltage could be correct but the output voltage will not. However, it is still a useful indicator as it will light up when the DC-DC converter is shut down or if the output cannot provide sufficient voltage under load. Of course, test voltages can be periodically checked with a multimeter.

Output terminals

As can be seen on the circuit, the positive output of the high voltage generator connects directly to the positive (red) test terminal while the negative test terminal is connected to circuit ground via two 1.5kΩ 1W resistors connected in series. These provide a means of monitoring the load current

for the Insulation Tester.

IC3c monitors the voltage across the resulting 3kΩ resistance via a 100kΩ resistor. This 100kΩ resistor protects the op amp's input should one of the 1.5kΩ resistors go open circuit and allow the full 250V or 500V to be applied. Diode D7 clamps the input to just over the +9V supply.

IC3c amplifies the voltage across the 3kΩ resistance by a factor of two when switch S2 is in the 250V position. In the 500V setting, S2 disconnects the associated 100kΩ resistor from ground and connects another 22kΩ resistor between pin 5 of IC1 and ground. As well as doubling the output from the high-voltage generator, it converts IC3c to a unity gain voltage follower. So either way, the following LED display circuitry involving IC5 gets the correct signal range which is fed via a 6.8kΩ resistor and 10kΩ trimpot VR2.

IC5 is an LM3915 logarithmic dot/bar driver and this drives the 10-LED display. An internal 1.25V reference at pin 7 sets the full-scale input voltage. IC5 is set in dot mode, meaning that only one LED in the 10-LED bargraph is driven at any one time.

For our circuit, full scale is when the LED at pin 10 is lit and this is labelled 707kΩ. Other LEDs show 1MΩ, 1.4MΩ etc, as mentioned above. If any of the 10 LEDs in the bargraph is lit, the resulting LED current through the 150Ω resistor from the +9V rail will produce a voltage to switch on transistor Q6 and it shunts LED4 so it cannot light.

If all the bargraph LEDs are off, Q6 will be off and LED4 will light, indicating that the load across the tester's terminals is more than 16MΩ. So in practice, with nothing across the test terminals, LED4 will be lit.

Over-current trip

As noted above, the trip circuit shuts down the high voltage if the leakage current exceeds 1mA in the 500V setting and 500µA for the 250V setting.

The over-current detection circuitry comprises op amps IC3a, IC3b, Q3 & Q4 and REF1. REF1 is an LM285 2.5V reference and IC3b buffers it and feeds the inverting input of IC3a at pin 2. IC3a's non-inverting input at pin 3 monitors the output of IC3c via a voltage divider comprising a 20kΩ and 100kΩ resistor.

IC3a is connected as a comparator. If IC3c's output goes above 3V, the load current through the two 1.5kΩ current monitoring resistors will evidently be above 1mA (for the 500V DC setting). So with a voltage just above 3V from IC3c, IC3a's output goes high and D5 pulls pin 3 up even further to ensure IC3a then stays latched. IC3a's high output then switches on Mosfet Q4 and it pulls down pin 4 (the reset input) of IC2. IC2 now acts as a gate and shuts off the drive to Mosfet Q2 to kill the output of the high voltage generator. At the same time, LED2 lights to indicate that the high voltage is off and the over-current circuit has tripped.

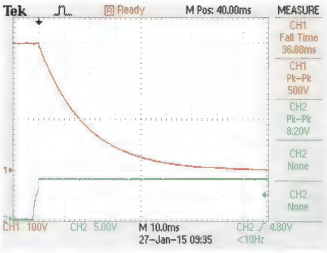


Fig.3: this scope grab shows the action of the trip circuit when the load current exceeds 1mA (for the 500V setting). The green trace shows the voltage across the 3kΩ monitor resistance and the orange trace shows the resulting exponential drop in the high voltage in less than 40ms.

In addition, diode D8 drives the gate of Mosfet Q3 to discharge the 100nF high-voltage supply capacitor via two 100kΩ resistors. And finally, diode D6 drives the input of IC3c to well over 3V so that the LED display will show a low reading, ie, "<700kΩ".

As mentioned previously, the high-voltage error LED (LED1) will also light to indicate that the high voltage has shut down. To return to normal operation, the Insulation Tester is simply switched off and on again.

Pushbutton switch S3 connects the two 100kΩ VR25/VR37 resistors on the positive high-voltage supply to the negative test terminal. The resulting current through the 3kΩ monitor resistance causes the circuit to trip out as described earlier. The trip test current is 2.5mA at 500V and 1.25mA at 250V. These test currents are more than twice the rated trip current but will at least verify that the trip current circuit will work.

If you are unfortunate enough to get a shock from this Appliance Insulation Tester, it shuts down the high voltage to safe levels within 40ms (much faster than any RCD is supposed to disconnect the 230VAC mains supply in the event of a fault or shock).

9V battery

A 9V battery powers the circuit and it is connected via switch S1 in the positive lead. Mosfet Q1 is connected in the negative lead to the battery and provides protection against reversed polarity (ie, when you connect the battery the wrong way around). If the polarity is correct, the internal diode in Q1 will conduct and Q1's gate will be driven to 9V via a 1kΩ resistor to switch it on. If the 9V is reversed, Q1's internal diode will be reverse biased and the Mosfet will remain off.

A low battery indicator is provided by op amp IC3d, connected as a comparator. It compares the 2.5V from

Specifications

Power: 9V at 25mA for a 500V output, 18mA for 250V (with >16MΩ leakage resistance), 110mA at 600kΩ leakage and 500V test voltage

Low voltage indication: 7.5V. Circuit operates down to 5V

Output voltage: 500V and 250V with <1% variation from no load to 1mA trip point

Leakage trip current: 1mA at 500V, 500µA at 250V

Trip test current: 2.5mA at 500V, 1.25mA at 250V

High voltage discharge rate: the 500V output drops below 50V in 40ms

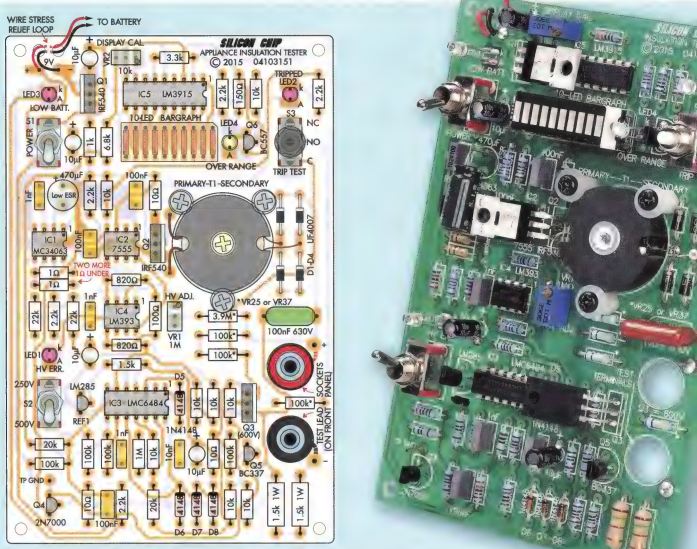


Fig.4: follow this parts layout diagram and the photo at right to build the PCB but don't solder the LEDs or connect the insulated banana sockets until after the front panel PCB is attached (see text). Figs.5&6 on the following pages show the transformer winding details.

REF1 with a sample of the battery voltage fed via the 20kΩ and 10kΩ resistors on pin 13. This will cause the comparator to switch its output to turn on LED3 for battery voltages of less than 7.5V. The 1MΩ resistor between pins 14 & 13 provides 135mV of hysteresis to stop any flickering of the LED. Note that the circuit will continue to operate down to about 5V.

Note also that we have not provided a separate power indicator LED since either the LED bargraph or LED4 will light whenever power is on.

Assembly

The assembly is straightforward, with all parts installed on a double-sided PCB coded 04103151 and measuring 86 x 133mm. A second PCB (coded 04103152, 90 x 151mm) is used as the front panel and this replaces the lid of the UB1 plastic utility box that's used to house the unit.

The two PCBs can be obtained either as part of a complete kit (ie, from parts retailers) or can be purchased as separate parts from the Silicon Chip Online Shop (www.siliconchip.com.au).

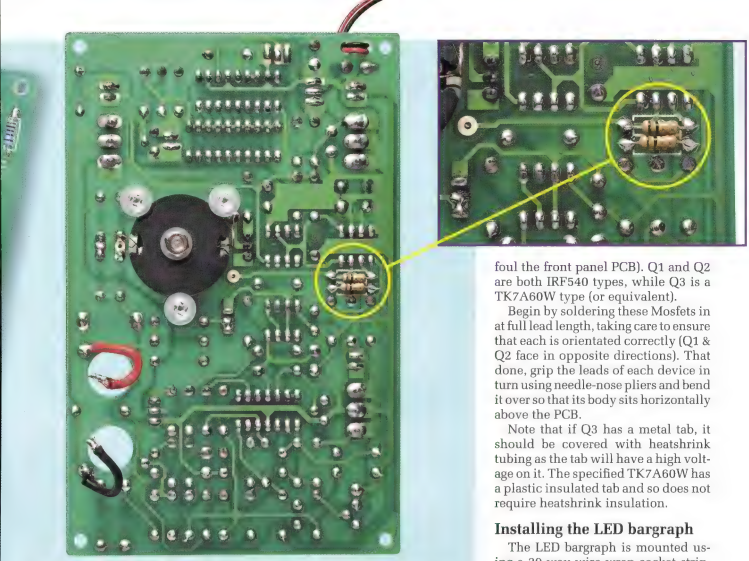
Fig.4 shows the parts layout on the main PCB. Begin by installing the resistors and diodes, taking care to ensure that the latter are correctly orientated. Table 1 overleaf shows the resistor colour codes but you should also check each one with a multimeter before fitting it to the PCB.

Two 1Ω resistors must be installed on the underside of the PCB. These are mounted directly under the two 1Ω resistors (located adjacent to IC1) and are installed in parallel with these two resistors. It's just a matter of soldering their leads directly to the pigtails of the top resistors.

Note that VR25 or VR37 resistors must be used in the positions marked with an asterisk (*). In addition, two different diode types are used – 1N4148 and UF4007. Be sure to install the UF4007 diodes adjacent to T1.

Once the resistors are in, install the three PC stakes. These are used for the positive and negative terminals adjacent to the test lead sockets and for the TP GND terminal (near Q4 at bottom left).

The ICs can now be installed. Make sure that the correct IC goes in each position and that it is orientated as shown on Fig.4. IC1, IC2 & IC4 are all 8-pin devices, so be careful not to get them mixed up.



The primary & secondary leads that emerge from the bottom of the transformer are soldered directly to their respective pads on the underside of the PCB. Note that two 1Ω resistors (circled) are also soldered to the underside of the PCB. These go directly under the two 1Ω resistors on the top of the PCB and are soldered directly to their solder pads, so that all four resistors are in parallel.

Follow with the capacitors, taking care to install the electrolytics with the correct polarity. Note that the 470µF capacitor (near power switch S1) must be a low-ESR type. Note also that the top of each electrolytic capacitor must be no more than 15mm above the PCB, to allow clearance for the front panel PCB. It may be necessary to mount the 470µF low-ESR capacitor on its side to meet this requirement, as shown in the photos.

Transistors Q5 & Q6 and Mosfet Q4 can now go in. Q5 is a BC337 NPN type while Q6 is a BC557 PNP type, so don't get them mixed up. The LM285Z (REF1) be also now be installed – it goes in to the left of IC3.

Multi-turn trimpots VR1 & VR2 are next on the list. VR1 (1MΩ) goes in with its adjustment screw towards the top edge of the PCB, while VR2's adjustment screw goes to the right. VR1 (1MΩ) could be marked as 105, while VR2 (10kΩ) may be marked as 103.

Now for the three switches. S1 & S2 can be installed either way around – just push them all the way down onto the PCB and make sure they are seated correctly before soldering their terminals. By contrast, S3 (at top right) must be orientated with its common pin towards the lower edge of the PCB. This pin is marked with a "C" on the switch side.

Power Mosfets

As shown in the photos, Mosfets Q1-Q3 must be mounted horizontally, with their leads bent down through 90° to go into their respective PCB holes (this is necessary so that they don't foul the front panel PCB). Q1 and Q2 are both IRF540 types, while Q3 is a TK7A60W type (or equivalent).

Begin by soldering these Mosfets in at full lead length, taking care to ensure that each is orientated correctly (Q1 & Q2 face in opposite directions). That done, grip the leads of each device in turn using needle-nose pliers and bend it over so that its body sits horizontally above the PCB.

Note that if Q3 has a metal tab, it should be covered with heatshrink tubing as the tab will have a high voltage on it. The specified TK7A60W has a plastic insulated tab and so does not require heatshrink insulation.

Installing the LED bargraph

The LED bargraph is mounted using a 20-way wire-wrap socket strip. First, break the socket strip into two 10-way strips and plug these into the bargraph pins. That done, insert the socket strips into the holes on the PCB with the bargraph's anode at top right, as indicated by the chamfer on one edge (see Fig.4).

Finally, solder the pins so that the top of the display is 18mm above the PCB. It's best to solder one end pin first, the adjust the display as necessary before soldering the diagonally opposite end pin. The remaining pins can then be soldered once everything is correct.

Winding the transformer

Fig.5 shows the transformer winding details. It's wound on a plastic bobbin which is then fitted into a pot core assembly.

The primary goes on the plastic bobbin first and is wound using 10 turns of 0.5mm enamelled copper wire (ECW). These turns are wound on side-by-side (ie, close-wound), with the wire ends brought out through the notched exit

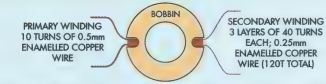
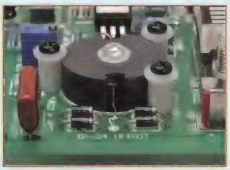


Fig.5: the transformer primary consists of 10 turns of 0.5mm-diameter enamelled copper wire (ECW), while the secondary is wound using 120 turns of 0.25mm-diameter ECW in three 40-turn layers. Note that one lead of each winding is brought out at the top of the bobbin, while the other is brought out at the bottom (see text & photos).



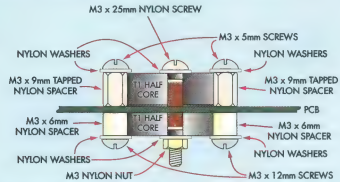


Fig.6: this diagram and the two photos at right show the mounting details for the transformer. It's secured in place using three sets of Nylon spacers, Nylon washers and Nylon screws.

points on the top and bottom of the bobbin. Once it's on, cover the winding with a layer of 10mm-wide insulating tape to hold it in place.

By contrast, the secondary consists of 120 turns of 0.25mm ECW and is wound using three 40-turn layers, each separated by a layer of insulation tape. As before, the start and finish windings exit from two notched exit points on the top and bottom on the bobbin.

The secondary is also close-wound but note that 40 turns will not fit side-by-side across the bobbin. This means that some of the turns in each layer will have to go directly over the top of the others. Ideally, each layer should start on one side of the bobbin and be wound progressively toward the opposite side of the bobbin. Make sure that all three layers are wound in the same direction.

Secure the top secondary winding layer with another layer of insulation tape to hold it in place.

The next step is to cut an 11mm OD spacer from 0.25mm-thick cardboard. This spacer is used to separate the two pot core halves (it produces an air gap which prevents saturation in the ferrite cores). Once you've cut the spacer to size, cut a neat 3mm hole in its centre.

The pot core halves can now be placed over the bobbin with the spacer between them (ie, the spacer fits inside the bobbin). Check that the four leads

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
10nF	0.01µF	10n	103
1nF	0.001µF	1n	102

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	3.9MΩ	orange white green brown	orange white black yellow brown
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	7	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	22kΩ	red red orange brown	red red black red brown
❑	2	20kΩ	red black orange brown	red black black red brown
❑	8	10kΩ	brown black orange brown	brown black black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	1	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	5	2.2kΩ	red red red brown	red red black brown brown
❑	1	1.5kΩ	brown green red brown	brown green black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	2	820Ω	grey red brown brown	grey red black black brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	3	10Ω	brown black black brown	brown black black gold brown
❑	4	1Ω	brown black gold brown	brown black black silver brown

The front panel PCB (with the insulated banana sockets fitted) is secured to the main PCB assembly by fitting it over the three switch shafts and doing up nuts on either side. Once it's in place, the LEDs are pushed through the front panel and soldered and the banana sockets connected to their respective test terminal pads.

from the bobbin exit through the core notches, then secure the core assembly using an M3 x 25mm screw, two Nylon washers (one at the top and one at the bottom) and an M3 nut (see Fig.5). Cut off any excess screw length using side cutters.

The transformer is now fitted into its hole in the PCB with its 0.5mm primary leads to the left (ie, near Q2) and its 0.25mm secondary leads to the right (near D1-D4). One lead on each side will exit on the top of the PCB, while the other two leads exit the transformer on the underside of the PCB.

Once it's in position, secure the transformer in place using three M3 x 9mm tapped Nylon spacers, three M3 x 6mm Nylon spacers and M3 screws and washers – see Fig.6. The ends of the windings can then be trimmed, striped of insulation using a sharp knife and soldered to their respective pads on the PCB.

All that remains before the calibration procedure is to install the battery snap connector. Loop its leads through the two strain relief holes as shown on Fig.4 before soldering them to their pads.

Note that LEDs1-4 and the two banana socket terminals are not installed at this stage.

Test & calibration

Before going further, note that the inverter circuit generates a high voltage (up to 500V DC) and this can give you a nasty shock. In particular, note that the trip current protection circuit only works for connections between the "+" and "–" high-voltage terminals. It's there to provide protection against accidental contact with the output terminals, mainly when the unit is installed in its case.

Conversely, any contact between the circuit ground (or any other low-voltage point on the circuit) and high DC voltage on the "+" output will not cause the circuit to shut down. So take care and apply power only when your other hands are safely away from the PCB.

To test the unit, you will need to first solder short lengths (eg, 10mm) of red and black mains rated wire to the "+" and "–" high-voltage PC stakes (the output sockets are not installed at this stage). The test and calibration

This adaptor cable makes it easy to connect one of the Insulation Tester's probes to both the Active & Neutral leads of the appliance being tested at the same time. It's made by cutting the socket and about 150mm of lead from the end of an extension cord, then connecting the socket's Active and Neutral wires together and terminating them in a solder eyelet. The Earth wire is cut back out of the way and the cable sleeved in heatshrink and marked. The appliance to be tested is plugged into this socket and one of the Insulation Tester's probes connected to the solder lug while the other probe goes to the appliance's external metalwork or chassis.

This is the view inside the completed Appliance Insulation Tester. The battery is clipped into a holder that's attached to the lefthand side of the case 15mm up from the bottom and between two sets of internal ribs.

procedure is as follows:
(1) Connect a multimeter using clip leads across these "+" and "–" high-voltage leads and set S2 to the 500V position.
(2) Apply power (keep your hands away from the leads) and check the high-voltage output. Assuming you get a reading, carefully adjust VR1 (using an insulated screwdriver) for a reading of 500V DC on the multimeter
(3) Set S2 to its 250V position and check that the reading is 250V.
(4) Switch off and connect a 1MΩ VR25 or VR37 resistor across the high-voltage terminal wires.
(5) Set S2 for 500V, apply power and adjust VR2 anticlockwise until at least the third LED (from the left) in the LED bargraph lights.
(6) Adjust VR2 clockwise until the second LED (the 1MΩ indicator) just lights, then set S2 to 250V and check that the unit shows the same 1MΩ reading on the LED bargraph. That's it – the calibration procedure is complete.

Final assembly

Now for the final assembly. First, insert LEDs1-4 into their PCB holes, noting that LED4 is green and that all LEDs mount with their anode lead towards the lower edge of the PCB. If the LEDs all have a clear body, you can usually determine which is the green LED by using the diode test feature on your multimeter. The LEDs may only glow dimly using this test but that's all that's needed to reveal the colours.

Don't solder the LEDs at this stage but just leave them sitting in place on the PCB.

Next, wind a single nut all the way down onto each switch mounting thread. Once these are in place, fit the red and black shrouded banana sockets to the front-panel PCB and secure them with the supplied nuts. Do the nuts up tightly, then fit the front panel over the three switches and push it down so that the LED bargraph goes into its rectangular hole.

Note that the corners of this rectangular hole may need to be "squared off" using a file so that the bargraph will fit.

Now adjust the three previously-fitted switch nuts so the LED bargraph display sits flush with the top of the front panel. Check also that the panel is parallel to the PCB, then fit nuts to the top of the switch threads and tighten them down to hold the assembly together.

The four LEDs can now be pushed into their front panel holes and their leads soldered. In addition, you will need to solder the high-voltage output leads to the banana socket terminals.

Preparing the case

Only a small amount of work is required on the case. The first step is to attach a mounting clip for the 9V battery to the inner lefthand side. That's done by drilling a 3mm-diameter hole some 15mm up from the outside bottom of the box and between two sets of ribs (see photo). The mounting clip can then be attached using an M3 x 10mm screw and nut.

In addition, the internal ribs on the case ends must be cut down, as they prevent the front panel from sitting directly onto the four corner pillars. This can be done using side cutters or a sharp hobby knife.

The 9V battery can then be clipped into its holder and the completed PCB and front panel assembly lowered into position and secured using the supplied screws. That done, switch it on and check that the output voltages (250V and 500V DC) are correct.

Finally, press S3 to check that the Trip function works correctly. If it does, LED2 should light to indicate that this has occurred.

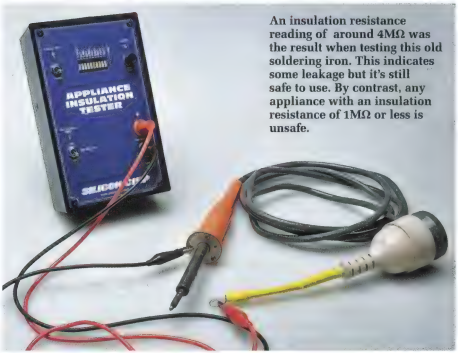
Testing appliances

When testing appliances, the condition of the mains plug, lead and earth connection (where used) will need to be checked. Make sure that mains wires are not frayed, repaired with insulation tape, broken or exposed. For earthed appliances, check the resistance between the Earth pin on the mains plug and any exposed metal. There should be less than 1Ω resistance when measuring with a multimeter set to the low ohms range.

The accompanying photos show how the Appliance Insulation Tester is used to test a mains appliance. **One probe is used to simultaneously connect to both the Active and Neutral pins of the mains plug, while the other probe connects to any exposed metal parts on the appliance. The appliance's power switch must be on.**

Note that some metal parts may be painted or anodised and so contact with bare metal will not be made with

This jigsaw gave an insulation resistance measurement of >16MΩ on the 500V test range, indicating that it is safe to use.



An insulation resistance reading of around 4MΩ was the result when testing this old soldering iron. This indicates some leakage but it's still safe to use. By contrast, any appliance with an insulation resistance of 1MΩ or less is unsafe.

the probe. The way around this is to scrape away any coating (without causing too much unsightly damage) so that a proper connection is made to the metal.

The Active and Neutral mains plug connection can be made using a large clip attached to the probe. Alternatively, the appliance could be plugged into an extension cord mains socket which has its Active and Neutral leads brought out, connected together and terminated in a crimp eyelet for easy connection to the tester – see photos.

Note that normally a 500V insulation resistance test should be made but when an appliance test fails because of internal over-voltage protection (eg, if MOVs are fitted), then a 250V test can be made instead.

Any appliance that has a measured insulation resistance of 1MΩ or less is unsafe. Note that this does not apply to portable RCDs that have a functional earth or for mineral insulated metal sheath heating elements (for more information refer to the latest AS/NZS 3760 standards). SC

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Got a Boat, Van, RV, 4WD, etc? Need Light?

Really Bright 12/24V LED Oyster Light

By Ross Tester

Here's a low-cost, 1000+ lumen, attractive "Oyster" LED light fitting for when you don't have mains available. Or even if you do! It runs from 12-24VDC or even from 230VAC with an optional (low cost) mains adaptor.

A few months ago (gad, was it really January 2013?) we presented a "LED Solar Skylight" from Oatley Electronics. It was (and still is!) very popular for introducing light into dark corners.

Now they've come up with another low-voltage LED-based light fitting which is ideal for boats, caravans, RVs and mobile homes, trucks, 4WDs . . . in fact, anywhere you have 12-24V DC available.

And it could also be used as a mains-powered LED light with a low cost, optional AC adaptor (albeit with a bit of fiddling).

There's virtually nothing to build with this one. The Oyster-style lamp housing is already fitted with a PCB containing 24 ultrabright, pure white LEDs in two concentric rings, connected in series/parallel.

In the centre of these is a driver PCB which supplies the 40V @ 260mA required by the LEDs

Overall current drawn from a 12V supply is around 1.1A, dropping to about 550mA from a 24V supply.

Light output from the Oyster fitting is more than 1000 lumens. Looking directly at it, you'd swear it was a lot more!

Incidentally, for comparison a traditional 36W fluoro tube puts out about 3500 lumens but that's over a much wider length.

Oyster size is about 260mm diameter x 75mm deep, so it's not too dissimilar to other domestic light fittings. An integral 235mm diameter aluminium backing plate/heatsink is designed to be screwed to a ceiling/wall/bulkhead/etc and the Oyster diffuser mounts on that via a twist onto three pins.

Now a quick word to the wise: the diffuser is made of quite thin (and somewhat fragile) plastic so if you go at it like a bull at a gate, you're liable to put your thumb or fingers right through it (we speak from sad experience, don't we boss. . .).

When disassembling, which is simply a matter of turning the diffuser with respect to the base, treat with a bit of care!

The LED driver

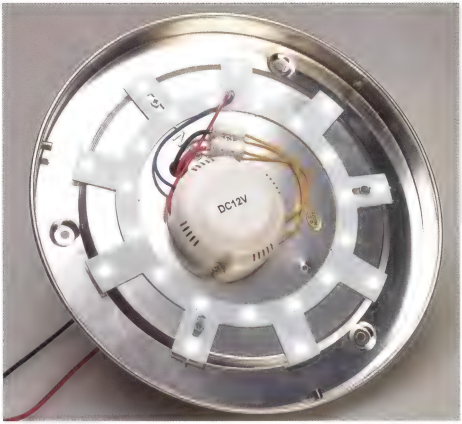
The driver PCB circuit is shown in Fig.1.

You don't need to worry about polarity of the DC supply as this is taken care of by a bridge rectifier at the input.

However, this results in a not-so-insignificant voltage drop across the two bridge rectifier diodes (2 x ~0.6V or about 1.2V).

Therefore you're effectively throwing away 10% if it is a 12V supply.

Directly feeding the filter capacitor (C1) rather than through the bridge would be more efficient, albeit at



24 ultra-high-brightness white LEDs are powered by an integral 12/24V driver (ignore the DC12V sticker!). The backing hardware also doubles as a LED heatsink.

the expense of the reverse-polarity protection provided by the bridge.

If you wanted to, you could feed the circuit with AC (obviously via the bridge) – say from 8 to 18 volts. However, this would require a much larger "filter" capacitor – the existing one is 100µF; you would need at least ten times this for AC (preferably more – 2200 or 3300µF would not be too much if it would fit). This capacitor is bypassed by a 100nF.

Power is applied directly to inductor L1 and IC1, a 60V, 4A switching current boost LED driver.

Inside IC1 is a switching Mosfet which turns on and off at about 180kHz. Every time it turns off, the magnetic field built up in L1 collapses, inducing a higher voltage at the anode of diode D5.

This is rectified by D5 and stored by capacitor C3/C4. Ordinarily, this voltage could be quite high but is limited to 56V by zener diode ZD1 (IC1's maximum voltage is 60V). If the voltage across C3/C4 exceeds 56V, the Zener conducts and stops the inverter by applying a voltage to IC1's feedback pin (pin 5).

The output voltage is further clamped to approximately 40V by the 24 high-brightness LEDs connected in series/parallel at the output. Effectively there are 12 LEDs in series, each dropping about 3.3V (12 x 3.3 = 40V).

The voltage at the feedback pin of IC1 (pin 5) controls the duty cycle of the Mosfet, while pin 2 (the enable pin) can be shorted to ground to stop the inverter working. We use this pin to allow it to "soft start" the inverter so it can be used with a switch-mode supply, as detailed shortly.

Operating on 230VAC

Oatley Electronics have a very-low-price switch-mode power supply (KC24) which can deliver 24V DC at up to 1A. On first glance, this would appear to be ideal for powering the Oyster LED light from the mains.

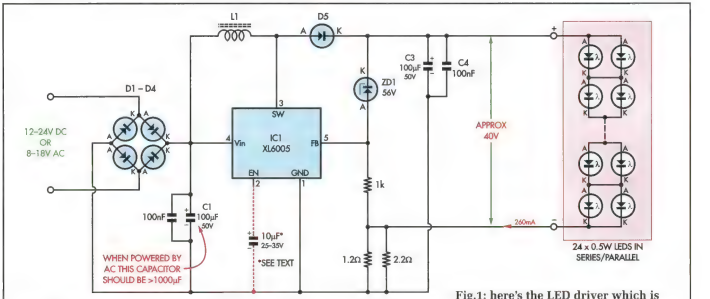


Fig.1: here's the LED driver which is contained in the white container at the centre of the photo above. It supplies around 40V DC @ 260mA from a low voltage DC or AC source.

Oatley's KC24 230V to 24V @ 1A switch-mode power supply. It's suitable for use with the Oyster LED light but that requires a small modification, as described in the text to stop the power supply shutting down at turn-on.

WARNING: 230V LED Driver

An alternative 230V AC LED driver (285MACC) is also available but **WE STRONGLY RECOMMEND THAT YOU DO NOT USE THIS DRIVER**.

It is **not an isolated supply** so the whole LED mounting base can become live – indeed we checked this driver with the Appliance Insulation Tester described elsewhere in this issue and it instantly tripped it (ie, isolation <700kΩ).

Stick to the **SAFE** 12/24V LED driver and if you want to run it from the mains, use the KC24 switch-mode supply as detailed above. Incidentally, we checked the KC24 supply with the same tester and it passed with flying colours.

Unfortunately, appearances can be deceiving!

By its very nature, the Oyster LED lamp has quite a high surge current at switch-on, which is enough to trip the over-current protection circuitry in the KC24 supply, which turns off almost straight away. The high surge current disappears, the power supply again tries to start, resulting in a high surge current . . . etc etc!

The result is that the Oyster LED Lamp "strobes" - a neat feature if you're having a party but not quite so good if you're looking for light!

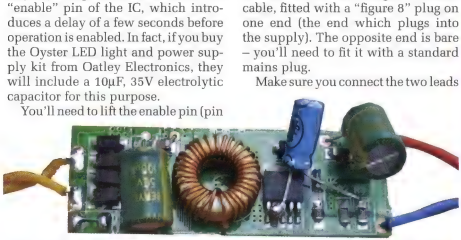
The KC24 power supply is sealed, so no adjustment is possible there (not that we'd want you to because it is a mains-powered device and can therefore "bite" very hard).

But it's easy enough to open up the LED driver in the Oyster LED Light and modify it slightly so that it "soft starts", eliminating that surge current.

All you need do is insert a small (say 10µF) capacitor in series with the "enable" pin of the IC, which introduces a delay of a few seconds before operation is enabled. In fact, if you buy the Oyster LED light and power supply kit from Oatley Electronics, they will include a 10µF, 35V electrolytic capacitor for this purpose.

You'll need to lift the enable pin (pin 2) off the PCB. It's not hard to do this as it is a surface-mount device – melt the solder with your soldering iron and use a hobby knife to prise the pin up, ensuring you've removed all the solder underneath (Solder Wick is handy for this).

Solder the positive lead of the capacitor to the pin (not the PCB!) and the negative lead to a suitable earth point – we used the top end of resistor R3, as shown in the photo. That's all there is to it.



Here's that modification required to the LED driver – a 10µF capacitor is added in series with the "enable" pin of the IC to slow its start down. This prevents it overloading the power supply and shutting it down. The PCB first needs to be removed from the white housing in the middle of the LEDs.

Power supply connections

Power wires, either 12-24V DC or 8-18V AC go through a hole in the back of the Oyster LED light, very close to the push-button terminal block. As we mentioned before, you don't need to worry about polarity so simply connect either wire to either terminal.

Mains supply

The KC24 power supply from Oatley comes with a short length of mains cable, fitted with a "figure 8" plug on one end (the end which plugs into the supply). The opposite end is bare – you'll need to fit it with a standard mains plug.

Make sure you connect the two leads to the Active and Neutral terminals in the plug – they're either labelled "A" and "N" or in some cases colour coded, usually red (Active) and black (neutral). In newer plugs, the colour coding may conform to the IEC colours of brown (Active) and blue (Neutral).

Do **NOT** connect anything to the plug's Earth terminal ("E", green or green-gold) and make sure that you slide the rear cover all the way onto the plug body.

The DC end will probably have a 4-pin DIN plug on it which has to be cut off. Stripping the outer insulation back will reveal four wires – red and black (positive) and green and white (negative). Note that – the black wire is definitely positive – it's a trap for young players.

You only need to use one pair of wires (ie, there's no need to parallel them), say the red and the green wires, for DC out. These go through the hole in the back of the Oyster LED light to the push-button terminal block. As we mentioned before, you don't need to worry about polarity. SC

Where from, how much?

The LED Oyster Light is available from Oatley Electronics, PO Box 139, Ettalong Beach, NSW 2257; phone (02) 4339 3429 (www.oatleyelectronics.com).

On its own, the LED Oyster Light as described here (with 12/24V LED driver) sells for $25.00, inc. GST, (Cat No K400). The KC24 230V AC to 24V DC switch-mode supply sells for $9.95 inc. GST.

However, at the time of writing Oatley Electronics are selling BOTH the LED Oyster and switch-mode supply for just $28.00 (Cat No K400P1), inc. GST.

And if you want two sets, the price reduces to only $50.00 for both inc. GST (Cat No K400P2). All prices are plus freight.

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ALSO AVAILABLE:

32GB MICROSD CARD XC-4992 **$47.95**

2-Channel Active Speakers XC-5120

Connect your PC or Smartphone to these stylish 2 channel speakers. Mains powered and supplied with a 3.5mm stereo audio cable.

- 3W output
- 170(H) x 90(D) x 70(W)mm

NEW

$19.95

Looks Great, Sounds Great

AA-2120

Listen to your favourite music in high fidelity with these professionally quality built stylish stereo headphones. Connect directly to your Smartphone, home theatre system and CD/DVD players. White colour.

- 3.5mm stereo plug

NEW

$34.95

Single Board Mini PC + Arduino = pcDuino!

pcDuino is a high performance and cost-effective mini PC combined with connectivity to Arduino shields. Capable of running KODI and operating systems such as Ubuntu and Android ICS, it has many amazing onboard connectivity options* such as HDMI, USB, SATA, LVDS and Wi-Fi so you can use it in robotics, home theatre, signage, electronic control and various other applications. This is the must have DIY development platform for all beginner to professional electronic enthusiasts!

Take your pcDuino projects to the next level by adding a 7" LVDS* colour LCD screen with capacitive touch capability (XC-4356). Extremely easy to install, this 1024x600 pixel interactive touchscreen display is the perfect addition for the pcDuino V3.

*USB & Wi-Fi only on XC-4350 * LVDS = Low-Voltage Differential Signaling

PCDUINO V3.0 NANO XC-4352

PCDUINO V3.0 WITH WI-FI XC-4350

7" LCD TOUCHSCREEN TO SUIT XC-4350 XC-4356

NEW

$89.95

XC-4352

NEW

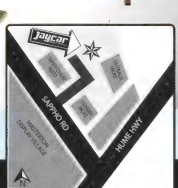
$139

XC-4356

NEW

$129

XC-4350



NOW OPEN: WARWICK FARM

CNR OF SAPPHO ROAD & HUME HIGHWAY
WARWICK FARM NSW 2170 PH: (02) 9821 3100

FREE 3m HDMI CABLE FOR REWARDS CARD HOLDERS*

WV-7916 VALUED AT $24.95

Convert Your PC To A Modern Media Centre

Enjoy high definition video with audio on your big screen. These smart devices convert your VGA equipment (computers, laptops) to newer HDMI equipped displays via the VGA or USB 3.0 ports.

VGA/USB TO HDMI CONVERTER AC-1639 **WAS $79.95**

USB 3.0 (VIDEO/AUDIO) TO HDMI CONVERTER XC-4973

VGA & R/L AUDIO TO HDMI SCALER CONVERTER AC-1617

$99 AC-1617

$64.95 AC-1639

SAVE $15

$89.95 XC-4973

FREE LCD SCREEN CLEANING KIT FOR REWARDS CARD HOLDERS* AR-1418

AR-1418 VALUED AT $9.95

DOUBLE POINTS ON THESE PRODUCTS FOR REWARDS CARD HOLDERS*

*Valid for purchases of XC-4906, XC-4871, XC-4879, PA-0897, PA-0896, YN-8075 or YN-8094.

CW-2833

FROM $49.95

LCD Monitor Desk Brackets

Securely mounts onto a variety of desk thicknesses for landscape or portrait positions. Features fully adjustable arms and standard VESA mounting with 10kg per monitor load. *Monitors not included.*

SINGLE CW-2831 **$49.95**

DUAL CW-2833 **$69.95**

DOUBLE POINTS

$49.95

Composite and S-Video to VGA Video Converter XC-4906

Ideal for connecting an old game console, VHS player, etc to your computer monitor or plasma TV. Has VGA loop through so you can have a computer and composite/S-video source connected to the same display.

DOUBLE POINTS

$69.95

VGA to Composite and S-Video Converter XC-4871

A versatile device that lets you use your wide screen plasma or LCD screen as a computer monitor. Great for watching DVDs, gaming, presentations, or just having a big screen on your computer. No software is required and powered from USB Port.

DOUBLE POINTS

$69.95

USB to DVI Adaptor XC-4879

Connect your monitor to the computer via the USB 2.0 port without buying additional graphics cards. Use up to 6 simultaneously to run screen arrays. Powered via USB.

WQ-7440

DOUBLE POINTS

$29.95 ea

Mini DisplayPort Converter Leads

Connect modern computers with a Mini DisplayPort® to a VGA, HDMI or DVI equipped monitor or projector. All leads 1.8m long.

- Mini DisplayPort® 1.1a compliant
- Supports up to 1980p resolution

VGA CONVERTER WQ-7440 **$29.95**

HDMI CONVERTER WQ-7442 **$29.95**

DVI CONVERTER WQ-7444 **$29.95**

DOUBLE POINTS

$12.95

DVI-A Plug to VGA Socket

PA-0897 **$12.95**

For connecting DVI-A or DVI-I video cards with VGA monitors.

ALSO AVAILABLE:

DVI SOCKET TO SOCKET ADAPTOR

PA-0896 **$14.95**

Compatible with DVI-I, DVI-D and DVI-A male connectors.

DOUBLE POINTS

$69.95

2-Port VGA/Audio Splitter

YN-8075

Splits a computers VGA and audio signal to two identical streams. The splitter provides fast, flexible solutions for test bench facilities, data centres or video broadcasting. Includes mains power adaptor and 1.8m male to female VGA cable.

- Bandwidth up to 500MHz
- Resolution up to 1920 x 1200 and 1080p

Limited stock. Available in-store only.

DOUBLE POINTS

$99.95

2-Port KVM Switch

WITH HDMI/MIC/AUDIO SUPPORT

YN-8094

Control 2 computers with one keyboard and mouse. Will also share stereo audio and mic so only one set of speakers/mic is needed.

- 1 x input cable with 2 x HDMI, 2 x USB and 2 x 3.5mm plugs
- 3 x HDMI to DVI adaptors included (1 for monitor, 2 for PCs)

WC-7590

DOUBLE POINTS

FROM $11.95

Monitor Cables

A variety of DVI, VGA and XVGA cables to suit your unique applications.

1.8M VGA DB15HD MALE TO DB15HD FEMALE WC-7500 **$11.95**

1.8M VGA DB15HD MALE TO DB15HD MALE WC-7582 **$11.95**

2.0M DVI TO DVI WC-7590 **$29.95**

5M XVGA DB15HD MALE TO DB15HD MALE WC-7588 **$39.95**

10M XVGA DB15HD MALE TO DB15HD MALE WQ-7258 **$49.95**

TELECOMS

$7.95

RJ12 6P/4C Wall Phone Bracket YT-6062

Designed to allow easy installation of telephones which have standard US modular wall mountings.

- Fits standard Australian electrical switch plate
- ACA approved

RJ12 6P/4C LEADS SOLD SEPARATELY:

5.0M YT-6049 **$7.95**

10M YT-6041 **$11.95**

15M YT-6043 **$14.95**

REWARDS CARD OFFER

BUY 2 FOR $23.90

SAVE $10

Cat 5 UTP Splitter

YT-6090 **$16.95**

Save time, money and space! Usually used in pairs, this UTP splitter enables two different devices to share the same Cat5 cable.

NOTE: Cannot be used to run two computers from one network and not suitable for gigabit networks.

FROM $14.95

IP67 RJ45 Connectors

High quality RJ45 connectors suitable for harsh environments.

RJ45 SOCKET PS-1450 **$27.95**

RJ45 PLUG PP-1452 **$14.95**

FREE IN/OUT THERMOMETER FOR REWARDS CARD HOLDERS*

*Valid with purchase of HB-5182, 2U or HB-5174, 12U HB-5180 series of Black Mesh Cabinets

XC-0321

XC-0321 VALUED AT $19.95

19" Rack Mount Cabinets

Jaycar's 19" rack mount cabinets are ideal for IT or phone system installations, studios and PA systems, with a size and configuration to suit your application. These cabinets are solid steel powder coated to provide high strength and rigidity under load and are packed flat for convenient transport. Coupled with our wide range of accessories and options, these 19" rack mount hardware are value for money and offer you outstanding features found on more expensive units. Unbeatable value!

TECH TIP! SAVE TIME & MONEY

Jaycar also stocks highly practical and value-for-money network installation and troubleshooting testers.

See our website or ask us now.

HB-5125

FROM **$64.95**

SAVE UP TO $20

Equipment Cabinet

ALUMINIUM FRONT PANEL

1U HB-5120
WAS $69.95 NOW $64.95 SAVE $5

2U HB-5125
WAS $109 NOW $99 SAVE $10

3U HB-5130
WAS $129 NOW $109 SAVE $20

FROM **$139**

SAVE UP TO $40

HB-5170

Fixed Frame

CLEAR TEMPERED GLASS DOOR

6U HB-5170
WAS $159 NOW $139 SAVE $20

12U HB-5174
WAS $229 NOW $189 SAVE $40

FROM **$199**

SAVE UP TO $40

HB-5182

Swing Frame

CLEAR TEMPERED GLASS DOOR

6U HB-5180
WAS $219 NOW $199 SAVE $20

12U HB-5182
WAS $299 NOW $259 SAVE $40

15% OFF THESE 19" RACK MOUNT ACCESSORIES FOR REWARDS CARD HOLDERS*

*See Page 8 for list of products

HB-5432

FROM **$24.95**

Rack Cable Supports

Take the pain out of wiring and fault-finding rack cabinets. These high quality supports keep your cables organised and neat, and provides strain relief at the same time.

1U HB-5430 **$24.95**

2U HB-5432 **$29.95**

$29.95

Patch Lead Management Panel HB-5434

1U size, keeps all your patch leads under control.

YN-8046

FROM **$49.95**

Cat 5/6 24-Port Patch Panels

Sleek attractive looking rack mount 24 port patch panel with a hard metal exterior. Numbered ports and a labelling area for each port.

1U, SUITS CAT5E YN-8046 **$49.95**

1U, SUITS CAT6 YN-8048 **$69.95**

$22.95

Cat5 Adjustable Punch-Down Tool TH-1740

Designed for seating wire into terminal blocks and has an adjustable internal impact mechanism. Supplied with 88 blade. 152mm long.

ALSO AVAILABLE:

110 REVERSIBLE KRONE BLADE TO SUIT TH-1743 **$17.95**

HB-5420

FROM **$10.50**

Blank Panels

Black powder coated panels for filling in unused space or configuring to your own requirements. Mount hardware included.

1U BLANK PANEL HB-5420 **$10.50**

2U BLANK PANEL HB-5422 **$12.95**

1U BLANK VENTED HB-5424 **$18.95**

1U BLANK VENTED HB-5426 **$27.95**

HB-5454

FROM **$49**

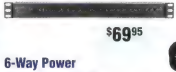
Rack Shelves

Ideal for equipment that you want to include in your 19" rack but doesn't have rack-mounting ears. Each shelf is punched with ample slots for ventilation and takes loads of up to 20kg.

1U FIXED SHELF HB-5452 **$49**

2U FIXED SHELF HB-5454 **$69**

1U SLIDING SHELF HB-5450 **$99**



$69.95

6-Way Power Distribution Unit MS-4094

Power up to six 240VAC components in your rack setup. Surge/overload protected and fits any standard 19" rack. Includes 1.6m power lead.

- 1U rack space

$19.95

6P/8P Modular Crimp Tool TH-1935

This tool will crimp 6P2C, 6P4C-RJ11, 6P6C-RJ12 and 8P-RJ45 plugs. Also cuts and strips the cable.

DOUBLE POINTS FOR REWARDS CARD HOLDERS ON THESE UNINTERRUPTIBLE POWER SUPPLIES*

*Valid for purchase of MP-5224, MP-5201, MP-5207 or MP-5212

DOUBLE POINTS

Protect your valuable setup with our value-for-money Uninterruptible Power Supplies. Keep your systems running long enough to save critical data when the mains power fails.

	MP-5224	MP-5201	MP-5207	MP-5212
Features	Line interactive, economical model	Line interactive, desktop model	Line interactive, smart LCD desktop model	On-line, smart LCD rack mountable (2U height)
Load Rating	600VA, 300W	650VA, 360W	1500VA, 900W	1000VA, 700W
Internal SLA Battery	12V/7AH x1	12V/7AH x1	12V/9AH x2	12V/7AH x3
Output Waveform	Modified Sine Wave	Modified Sine Wave	Modified Sine Wave	Pure Sine Wave
Transfer Time	<10 ms	<10 ms	<10 ms	Instant
Power Outlets	6 x AUS (3 bypass, 3 mains)	2 x AUS mains	2 x AUS mains	6 x IEC
Backup Time (Typical)	31 mins / 11 mins / 4.5 mins	25 mins / 9 mins / 5 mins	94 mins / 49 mins / 31 mins	55 mins / 47 mins / 32 mins

$99
MP-5224

$449
MP-5212

$99
MP-5201

$299
MP-5207

WIRELESS SURVEILLANCE SOLUTIONS

REWARDS CARD OFFER
BUY 2 FOR $159
QC-3834
SAVE $39

VGA 480p
QC-3834
$99

REWARDS CARD OFFER
BUY 2 FOR $299
QC-3844
SAVE $39

HD 720p
QC-3844
$169

NEW

Wireless Surveillance Package

REWARDS BUNDLE:
VALUED AT $328
BUNDLE DEAL INCLUDES:

BASE UNIT WITH 1 CAMERA QC-3675 **$219**
Simple to install wireless surveillance system with 7" LCD and infrared camera for day/night recording to microSD card (sold separately). Expandable up to 4 cameras.

ADDITIONAL CAMERA QC-3677 **$109**

REWARDS CARD OFFER
BUNDLE DEAL!
$249
SAVE $79

Monitor Your Workspace From Your Smartphone

Create a professional monitoring system with these DIY Wi-Fi IP cameras. Features pan/tilt and infrared LEDs for maximum visibility day or night. View live feed with your smartphone using free to download App, broadband required.

TECH TIP! BENEFITS OF IP CAMERAS

- Remote accessibility
- Integration with other systems
- Two way communications

.....and MORE! Ask us about our full range.

UHF CB RADIOS

REWARDS CARD OFFER
BUNDLE DEAL!
$199
SAVE $29.95

REWARDS BUNDLE:
VALUED OVER $228
BUNDLE DEAL INCLUDES:

5W UNDER-DASH UHF DC-1120 **$149**
Compact under-dash unit with long transmission range up to 20km line of sight*. Features 80 channels, channel scan, repeater access, CTCSS, and signal strength meter. Microphone, lead and mounting bracket included.

HIGH GAIN ANTENNA to suit DC-1120. UHF 5dBi with 5m cable. DC-3078 **$79.95**

3W Floating UHF

DC-1074 **$119**
A robust floating 80-channel transceiver with transmission range up to 10km line of-sight*. Featuring CTCSS function, Hi/Lo power output, auto squelch function and low battery display. Includes a Li-ion rechargeable battery, AC adaptor and charging cradle.

- IP67 rated

REWARDS CARD OFFER
BUY 2 FOR $199
SAVE $39

*Typical open field (line-of-sight), range will vary in built-up areas.

AC-1730

FROM $64.95

$89

$119

HDMI Extenders Over Cat5e/6

Extend your HDMI signal using Cat5e/6 cable. Use your remote-in either location with the built-in infrared transmitter.

30M* with 2 x Cat5e/6. AC-1730 **$64.95**
50M* with 1 x Cat5e/6. AC-1732 **$139**

*Depending on cable used and resolution. See website for details.

Composite AV Extender Balun over Cat5 QC-3681

Transmit crystal-clear audio and video signals over long distances via economical Cat5 cable. Ideal for extending the range of your remote control. The signals can be transmitted up to 300 metres on UTP.

SPARE IR RECEIVER
AR-1819 **$19.95**

VGA Extender over Cat5 AC-1671

Transmits VGA and audio signals across a standard CAT5 cable for distances up to 300 metres. Suitable for VGA cable runs through existing wiring in a wall or ceiling. Sender and receiver pair with plugpacks included.

- Supports up to 1920x1200 resolution

DOUBLE POINTS NEW

FROM $49.95

MP-3332

DOUBLE POINTS NEW

$59.95

Keep Your Laptops/USB Devices Charged!

Replace your lost or broken laptop charger without having to buy the expensive branded replacements. These mains power supplies include 1A or 2.1A USB charging ports and quick-change output plugs. *See website for specifications and compatibility.*

65W FIXED-SLIM MP-3321 **$49.95**
90W AUTOMATIC-SLIM MP-3322 **NEW $79.95**
120W FIXED-SLIM MP-3329 **$89.95**
144W MANUAL MP-3471 **$119**

90W Automatic Car Laptop Power Supply

MP-3323
High efficiency, ultra-slim power supply with automatic output that connects to your car's cigarette lighter socket. Features a 2.4A USB port, LCD display and includes 13 interchangeable plugs to suit most laptops. *See website for compatibility.*

- Input voltage: 12VDC
- Output voltages: 14-24VDC / 5VDC (USB)
- Output current: 6A / 2.4A (USB)
- 64(L) x 50(W) x 17(H)mm

DOUBLE POINTS ON THESE REPLACEMENT BATTERIES AND CHARGER FOR REWARDS CARD HOLDERS*

*Valid for purchases on SB-1770, SB-1771, SB-1772, SB-1775, SB-1503, SB-1504, SB-1651, SB-1646, SB-1634, SB-1648 or MB-3563.

FROM $11.95

DOUBLE POINTS

Non-Rechargeable Computer Backup Batteries

High capacity batteries used in many computers to retain critical system information while the computer is switched off.

HALF AA 900mAh SB-1770 **$11.95**
HALF AA WITH TAGS 900mAh SB-1771 **$13.95**
AA 2000mAh SB-1774 **$16.95**
AA WITH TAGS 2000mAh SB-1775 **$18.95**

Rechargeable Cordless Telephone Batteries

Suitable for Uniden or Panasonic cordless phones, all batteries are wrapped with suitable connectors.

See website for compatibility or speak to us to find a suitable replacement battery for you.

SB-1654

FROM $14.95

DOUBLE POINTS

BATTERY TYPE	GP BATTERY NO.	PRICE
2.4V 650mAh Ni-MH	65AAAH2BMS	$17.95
2.4V 650mAh Ni-MH	65AAAH2BMJ	$17.95
2.4V 800mAh Ni-MH	80AAM2BMS	$17.95
3.6V 850mAh Ni-MH	GP85AAAH6BMS	$14.95
3.6V 850mAh Ni-MH	GP85AAAHJ6BMS	$28.95
3.6V 1000mAh Ni-Cd	GP100AAS3BMS	$16.95

DOUBLE POINTS

$34.95

Panasonic Ni-MH Battery Charger MB-3563

Charges both AA and AAA Ni-MH batteries. The included Eneloop batteries are pre-charged and will last over 3 times longer than regular rechargeable batteries.

- Includes 4 x AA Eneloop rechargeable batteries

BUILD YOUR OWN ARDUINO SERIAL ADAPTOR

FOR DATA AND TELEPHONE COMMUNICATIONS
DOUBLE POINTS FOR REWARDS CARD HOLDERS*

*Valid for members of Nos 1449, 80, 8805, 10, 8807, 8, 8808, 9, 8809, 11, 8810, 12, 8811, 13, 8812, 14, 8813, 15, 8814, 16, 8815, 17, 8816, 18, 8817, 19, 8818, 20, 8819, 21, 8820, 22, 8821, 23, 8822, 24, 8823, 25, 8824, 26, 8825, 27, 8826, 28, 8827, 29, 8828, 30,

PERIPHERALS ON SPECIAL
NEW LOW PRICES UP TO 40% OFF
STOCK IS LIMITED. ACT NOW TO AVOID DISAPPOINTMENT.

SAVE UP TO 40%

AM-4073

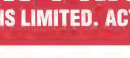
Desktop Multimedia Microphones

Ideal for voice recognition software or simply recording voice and sound. Low noise levels and wide frequency response.

OMI-DIRECTIONAL MICROPHONE
AM-4087 **ORRP $12.95 NOW $9.95 SAVE $3**

UNI-DIRECTIONAL GOOSENECK MICROPHONE AM-4073
ORRP $69.95 NOW $39.95 SAVE $30

SAVE 25%



Foldable Keyboard
WITH BLUETOOTH® TECHNOLOGY
XC-5202
ORRP $39.95 NOW $29.95 SAVE $10
This full 66 key keyboard folds in half from a 295mm to a modest 133mm so it's easy to transport without damaging the keys. Bluetooth® wireless technology means no annoying cables at all.

SAVE 20%

USB KVM & Transfer Cable XC-4949
ORRP $49.95 NOW $39.95 SAVE $10
Control another computer or transfer files between PC, Mac or even Android devices without the hassle of a network. Plug and play, no software needed on PC or Mac.
Free App available for Android.

MUST HAVE TOOL KITS

30pc Electronic Tool Kit
TD-2107 **WAS $29.95 NOW $24.95 SAVE $5**
An electronic tool kit with all the essentials - cutters, pliers, screwdrivers etc. Ideal for servicing the computer.*

SAVE 15%

SAVE UP TO 40%

WC-7510

Adaptors and Cables

USB A SOCKET TO A PLUG ADAPTOR RIGHT ANGLE UP
PA-0926 **ORRP $7.95 NOW $5.95 SAVE $2**

5 PIN PLUG TO 6 PIN MINI DIN SOCKET ADAPTOR
PL-0940 **ORRP $7.95 NOW $4.95 SAVE $3**

5 PIN SOCKET TO 6 PIN MINI DIN PLUG ADAPTOR
PL-0941 **ORRP $7.95 NOW $4.95 SAVE $3**

RS232 EXTENSION LEAD – 3M
WC-7510 **ORRP $19.95 NOW $15.95 SAVE $4**

RS232 SERIAL LAPLINK CABLE – 1.8M
WC-7514 **ORRP $19.95 NOW 11.95 SAVE $8**

PA-0926

SAVE UP TO 35%

CW-2870

Articulating Monitor Brackets

Position your monitor to the optimum viewing angle. Tilt the monitor up 90°, down 45°, pan it 180°, and rotate around a 360° range. Both models conform to the standard VESA mount.

WALL MOUNT CW-2872 **ORRP $99 NOW $79 SAVE $20**
DESK MOUNT CW-2873 **ORRP $69 NOW $59.95 SAVE $9.05**

ALSO AVAILABLE FOR iMAC:
WALL MOUNT CW-2871 **ORRP $79 NOW $47.95 SAVE $31.05**
DESK MOUNT CW-2870 **ORRP $89 NOW $59.95 SAVE $29.05**

SAVE 30%

19pc Repair Kit for iPhone
TD-2113 **WAS $29.95 NOW $19.95 SAVE $10**
All the tools you need to take apart your iPhone for DIY repair jobs.*

**Special only, new lower prices do not apply. See website for full contents of tool kits.*

Jaycar REWARDS

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 REWARDS CASH CARD ONCE YOU REACH 500 POINTS! *Conditions apply. See website for T&Cs.

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SERVICEMAN'S LOG

I hate letting anything beat me

Dave Thompson*

It seems I just can't help myself – unable to resist a challenge, I often take on jobs that are clearly not worth doing. I just hate letting anything beat me and that certainly applied to a no-name multi-tool I was recently given to fix.

Items Covered This Month

- Faulty multi-tool motor
- Reorganising a Howard organ
- PA amplifier repair
- DSE Q1418 multimeter

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These days, having a workshop packed with cool tools isn't as financially crippling as it used to be. The advent of cheap, imported but still high-quality tools means that once-expensive (and often hard-to-source) workshop tools are now very affordable. What's more, the abundance of warehouse-style tool retailers up and down the country means that they are readily available to anyone who wants to increase the capabilities of a home and/or business workshop.

It's no longer a matter of simply choosing between cheap, mass-produced rubbish and expensive European, American or locally made professional-level tools. Now we have a huge variety of very reasonable DIY or home-handyman grade tools to choose from but as with everything else, this can be both a good and a bad thing. These mid-range tools are often good quality and with care, can sometimes be used in a professional or commercial capacity. In most cases though, they wouldn't quite cut the level of "abuse" that goes with professional use.

Such tools generally come with a "DIY" or "Home Handyman" warranty to reinforce this fact, meaning that a tool will be repaired or replaced provided it hasn't been used to do work it hasn't been designed to do. In the case of a hammer or similar tools, this doesn't really matter but in other cases, it is important that tools are used strictly for the purpose for which they were designed. Exceeding their capabilities could result in tool failure and a serious case of missing appendages!

One of the downsides to the proliferation of reasonably-priced tools is that many of them are not worth repairing if they fail. In fact, depending on their quality and purpose, this happens far more often than with those high-quality jobs from Europe and the US.

I still have many of the tools I was issued over 35 years ago when I was a pimply-faced apprentice, starting my working career at our national airline. Many of my tools were made either in Europe or America and the quality is obvious as soon as you pick them up. Those with ratchets or other moving parts still operate like the day they were made and will most likely be still going strong long after I am no longer able to use them.

The biggest disadvantage of my original toolkit is that the majority of those tools are based on Imperial measurements. The reason for this is simple – the aircraft we were working on used good old inches and foot-pounds for their parts (airliners didn't go metric until relatively recently). Of course, those tools were fantastic when I owned British-made cars and motorbikes but they became all but useless when I started buying better-equipped (and better-engineered) Japanese vehicles.

That's why I now have two distinct sets of tools: my high-quality aircraft-engineer era tools in one set and the tools I've purchased since then in the other. The latter are, I have to admit, not quite as top-end as the others.

This is down purely to economics. Where possible, I invest in the best tools available (much to the distress of my significant other) but while my philosophy is that buying good tools is never a waste of money, there is a limit to that approach. Some tools are ridiculously expensive and it makes no sense spending hard-earned money on them when there are alternatives available that are "just-as-good-for-what-I'm-doing" for a whole lot less.

That said, I did like the culture of "nothing but the best" during my work with the airline (which set me up to strive for nothing but the best in the rest of my endeavours). Of course, "nothing but the best" is great when someone else is picking up the bill for all the nice tools!

Most older readers can probably relate to the following scenario: many years ago, you bought a screwdriver set at a tool sale and the very first time you tried to use one, the tip twisted or was stripped when you tried to undo a screw. The rest of the set then ended up

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...I OFTEN TAKE ON JOBS THAT ARE CLEARLY NOT WORTH DOING

gathering dust under the workbench because they simply weren't up to the job. These days though, quality tools are so much more affordable and available that this type of scenario now rarely happens.

Even so, with tools you usually get what you pay for. For example, a few years ago, I invested in one of those rotary engraver type tools that usually come in a moulded plastic case with a gazillion different cutting, grinding and drilling attachments. Dad had a Dremel-branded model and I coveted that tool for years but to buy one back then was still prohibitively expensive until the low-cost generic models hit the market.

While the Dremel tools did come down in price a little, you could buy a no-brand multi-tool for much less money and, by and large, it would do exactly the same job as the big-name models. Mine even came with a flexible shaft and a very handy hanger-type arrangement so it became almost like a dentist's drill, useful for carving, shaping, drilling and all sorts of jobs.

What's more, it got a lot of work. As part of my computer repair workshop, it did everything from drilling holes to chopping and channelling cases using the cutting discs. It was also used for shaping polymer fillers with the sanding attachments.

The tool even came with a new set of brushes but they are still sitting unused in their little plastic bag. In fact, they are not likely to be used now as I eventually inherited Dad's Dremel and that now graces my workbench. The only real difference – and I suppose this is where the money comes into it – is the quality of the speed controller. The controller on the Dremel is much smoother and easier to adjust than on my no-name model.

Of course, I could use one of the excellent SILICON CHIP designed speed controllers on the old no-name model. However, it now sits unused and will remain that way while the Dremel is still going strong. And that's after many years of use.

Multi-tool sob-story

So what's all this leading up to? Well, a good friend of mine turned up the other day with a very familiar-looking plastic case and a sob-story to go with it. It turns out that he had seen my original multi-tool in my workshop a few years back and had decided then and there that he should also have one. He builds houses for a living so I'm not entirely sure what he wanted it for but nonetheless, he went out and purchased one exactly the same and here it was, a couple of years later, sitting on my workbench.

I opened the case and it still sparkled with that brand-new look that tools have when they've never been used. My friend said that after originally buying it, he took it home, plugged it in and tested it before putting it back in its case, ready for use when the time came. When that day arrived, he took it out of the case, plugged it in and . . . nothing; it didn't work.

At the time, he did all the usual checks. He checked the brushes, tried another wall socket and did whatever else he could think of before deciding it was dead. Unfortunately, by then, he'd lost the receipt and since it had been quite a few months since he'd purchased it and because he'd bought it on sale from one of those big hardware chain stores, he figured it unlikely they'd consider taking it back without proof of purchase.

He told me that the price was pretty low anyway and it wasn't worth the grief of going through the motions to return it. In the end, he simply put it back in its case and stashed it away, forgetting all about it until he was recently having one of those "once-in-five-years" spring clean-outs. That's when he rediscovered it and so he brought it around to my workshop, thinking that I might be able to do something with it.

He didn't want to waste my time and any more of his money on it so he said that if I could get it going, I could have it. He'd long since resigned himself to the fact that it was dead and if I couldn't get the handset/motor going, then at least I could use all the cutters, drills and grinding wheels that came with it.

Never one to look a gift horse in the mouth, I accepted his challenge knowing full-well it would be unlikely I'd get this thing going. Most of these units have potted electronics and it was likely I'd open it up, take one look and throw it in the bin (after scrounging any reusable bits and pieces). As it turned out, I was to be pleasantly surprised.

Opening it up was simple as it didn't use any of those horrible "security" fasteners (the ones with a weird-shaped hole and sometimes a raised dot in the middle that requires a specially-formed, hollow screwdriver tip

to undo). Instead, six ordinary PK-style screws held the two plastic halves of the case together and while they were very tight, I soon had them out.

The fit of the parts was actually very good compared to some tools I've pulled apart in the past. The top half of the case came away easily, leaving the internals sitting in the bottom half. The armature was mounted on two sealed bearings – one at the front near the chuck and one at the rear supporting the very end of the armature. The brush holders sat at the three and nine o'clock positions and were part of the bottom half of the case.

Next, I undid the two plastic grub-type screws and removed the brushes before going any further. By lifting everything up a few centimetres, I could slide the armature out towards the front and it came out easily with the bearings attached. This left the fields, speed controller board and wiring, along with the mains cord which was terminated in a couple of screw-terminals on the controller board after passing through a strain-relief clamp at the very end of the case. That clamp was held in place with two short PK screws, as was the speed controller board, and after removing them the whole caboodle could be removed from the case.

With the plastic parts placed aside, I set about inspecting the electrics and other components. Surprisingly, the controller board was made up of discrete components that even had the values clearly marked on them, an unusual find when the manufacturers of many similar units do everything possible to obfuscate the parts used and the way they're wired in. That's usually done by sanding the surfaces of any ICs in the board to obliterate type numbers and by using potting materials to coat and cover the entire circuit board.

However, regardless of the fact that nothing had been obscured, I hoped that I didn't have to dig too far into the electronics side of the thing. Mains power and fiddling about with unfamiliar circuits don't go hand in hand, particularly as this whole circuit operated at mains potential!

Nothing obvious

There was nothing obvious on the board to explain why the unit had suddenly stopped working; no burnt patches, no melted wires and no acrid smells to indicate anything had become too hot or had let the magic smoke out. I could always just replace components until it started working again but my instincts told me that the board was OK so I'd have to look further afield (no pun intended!).

The wound stator fields had been tied with waxed string and dipped in varnish, making them one solid lump of wound copper wire and metal laminates. I checked where the controller wires and brush holder leads joined onto the fields (a common location for faults) and the connections seemed to be OK.

I then decided to check for continuity across the fields and brush connectors with my multimeter, so I it set to a low ohms range, and applied the meter's probes to the relevant connections. I got a satisfying beep between one brush connector and one output lead of the speed controller board and an indication of few ohms. However, I wasn't particularly interested in figures at this stage because I didn't know what it was supposed to measure anyway; the fact that I got some measurement at all was enough.

Conversely, I got nothing on the other side, which explained why the motor didn't work. I triple-checked that I was measuring the right connections but that's where the fault lay. It was in the fields somewhere and at that point I felt even less confident I'd have a fix up my sleeve. I turned everything off and went inside – I'd had enough for the night.

The next afternoon, I went back to it for a closer look. Before I got under way, I mounted and wired in my "new" 10W LED work light, a project I'd built up some time ago from a SILICON CHIP article and had been meaning to rig up for ages. This lamp throws out an enormous amount of light and amply covers my work area. This job would be an ideal acid test for it to see if I could visually discover why this coil didn't have continuity from one end to the other.

Under the light and with my magnifying headset on, I carefully inspected the whole assembly and a slight flaw in the coils at the top inside edge of the stator soon caught my attention. It looked as if something had hit the coils with a sharp edge (or it had been dropped onto something) and this had left a definite dent and barely-visible line across a few of the windings.

The varnish was holding it all together so I soaked the area with a few drops of "turps" and got stuck in with my dentist's pick, carefully cleaning the area of varnish which had softened and could now be easily scraped off. It was a painstaking job but suddenly a wire popped free, indicating the location of the break.

With one meter probe clipped to the brush holder, I touched the end of the broken wire with the other probe and got a satisfying "beep". A bit more turps and digging then revealed the other end of the wire and again with great care I

coaxed it free of the coil. I was then able to measure continuity between this wire and the speed controller board so all I had to do was join the two wires and I was away.

To keep things tidy, I brought the ends of the wires out to the upper edge of the fields and used a similarly-sized piece of wire to make up the resulting gap. Once soldered, I put a piece of insulation tape under the join and moulded the joined wire into the shape of the fields before coating it all in two coats of nail varnish.

I could then measure continuity from both brush holders to both ends of the speed controller board and after reassembling the tool, it worked perfectly. Since I didn't need another one, I returned it to my friend who was impressed and surprised I'd gone to so much trouble.

I told him what any servicemen would say: "I don't like letting anything beat me"!

PA amplifier repair

R. W. of Christchurch, NZ recently parted with coin of the realm for an old PA amplifier. It came complete with several faults which he managed to track down . . .

This is a short tale about a PA amplifier I bought for $30 at the Christchurch City Council recycling shed. It was an Inkel 2500D rated at 120W and featured a 100V line output, two balanced mic inputs, one unbalanced mic input and two auxiliary inputs.

When I got it home, all the inputs worked fine so I tested it into a dummy load at 100V. The power transformer buzzed like crazy so clearly it had a serious fault somewhere.

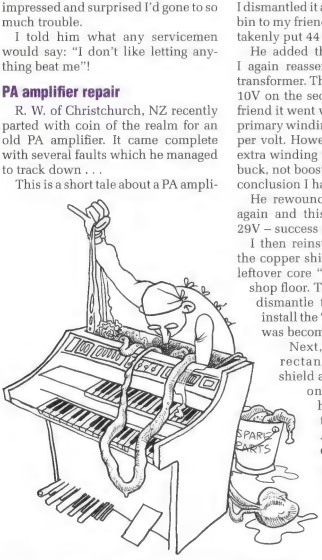
I soon found that the power transformer had a cooked secondary. I removed it, dismantled the core and made a new (non-standard) bobbin. A friend then rewound the primary and secondary windings after which I reassembled the transformer for a test but found only 20V on the secondary instead of the 29V required. As a result, I dismantled it again and returned bobbin to my friend who said he had mistakenly put 44 turns on instead of 64.

He added the extra 20 turns and I again reassembled and tested the transformer. This time, there was only 10V on the secondary so back to my friend it went who confirmed that the primary winding was OK at 2.22 turns per volt. However, he had added the extra winding turns in anti-phase (ie, buck, not boost), which was the same conclusion I had come to!

He rewound the added turns yet again and this time the result was 29V – success at last!

I then reinstalled the clamps and the copper shield, etc, only to find a leftover core "I" piece on the workshop floor. That meant that I had to dismantle the clamps again and install the "I" piece properly. This was becoming tedious!

Next, I tried to refit the rectangular hollow steel shield around the transformer only to find that this has to be done before the clamps are fitted. And so I removed the clamps again, fitted the shield, then fitted the clamps yet again and reinstalled the transformer in amplifier. The transformer voltage was correct and the amplifier's output measured OK but the sound was absolutely horrible during a low-level music test.



REORGANISING A HOWARD ORGAN

I applied an 800Hz test tone and observed massive crossover distortion on the scope. I then discovered that the first transistors in the power amplifier chain had 1.55V of forward bias on them. This came from a regulated 17V supply via an 8.2kΩ dropper resistor and a 1kΩ shunt resistor to ground, plus a 100µF electrolytic capacitor across the shunt.

I soon discovered that this 100µF electro was leaky but there was more – someone unknown had tacked an extra 15kΩ resistor across the 1kΩ resistor. The capacitor was replaced and the extra resistor removed, after which the bias voltage increased to 1.6V. And that eliminated the crossover distortion – it was no longer audible and what's more, it was no longer visible on the scope.

Here's hoping it stays that way!

DSE Q1418 multimeter repair

Regular contributor B. P. of Dundathu, Qld likes snapping up bargains on eBay but not all secondhand gear works properly. Here's how he recently saved an old DSE multimeter from landfill . . .

In amongst a bundled lot I recently bought on eBay was a DSE Q1418 multimeter. This unit arrived without the battery (due to postage regulations) and I noticed that one of the screws holding the back cover on was missing.

These DMMs are quite handy as general-purpose meters. I already have a couple of Digitor Q1467 multimeters and this DSE multimeter appears to have been made by the same manufacturer as they are virtually identical.

After fitting a replacement battery, I turned the unit on but nothing happened. I was sure that the battery was good but I used one of my other multimeters to check it, just to make sure. Sure enough, it tested good at 9.5V so there was obviously a fault in the unit somewhere.

With the unit switched on, my first step was to check the supply voltage where the battery leads connected to the PCB. Strangely, the voltage here was well under 7V but it still gave a reading of 9.5V at the battery terminals. That meant that the fault had to be somewhere between the battery and the PCB.

When I was replacing the battery, I'd noticed some slight corrosion on

Reorganising A Howard Organ

Here's something completely different: a Howard Skyline 100 electronic organ. B. B of Little Mountain, Qld recently took on the repair . . .

The Howard Skyline 100 electronic organ is quite a nice unit with a dual manual keyboard and foot pedals. This one was completely dead but I felt that it shouldn't be all that difficult to get it going again, despite the fact that there is nothing about this unit on the internet.

Removing some clips allowed the back panel to be removed, after which a collection of PCB assemblies was observed. Removing two screws then allowed the filter switch panel to be hinged out of the way, while removing two more screws made everything else accessible. This looked like an American product from the early 1970s and it was designed to be repaired!

The main reason the organ produced no sound was that a diode had died in the power supply and had taken out the fuse. That was easily fixed. Now there was sound but a few notes sounded decidedly sick. This fault was traced to a tone generator IC which was apparently very popular in the early 1970s. The keyboards worked but the rhythm section was also faulty and did not work.

One board had a number of CMOS logic gates, some of which oscillated at around 14MHz. If this was the rhythm section, it would be difficult to hear any sound as the drum frequencies would be 1000 times higher than our hearing range! Another IC generated sawtooth waves at around 40kHz.

After prodding around for some time, I eventually concluded that the 40kHz IC had something to do with the rhythm section, as one of its pins was connected to the rhythm speed control pot. This control pot had a very high resistance and it was difficult to determine just where the wiring at the other end ran to.

The part number identification on the rhythm IC was unreadable but then came an internet breakthrough. One of my many searches eventually turned up a rhythm generator circuit for organs. The speed control pot was between the 40kHz pin and earth and was designed to control the oscillation frequency.

The speed control pot was a 1960s slide potentiometer and getting one of these would be difficult. But this wasn't the time or place to give up so I dismantled the pot and took a look at its internal parts. This revealed that the sliding contact blade had been dislodged and had been crushed into the lower corner.

After bending the contact blade back into a reasonable shape, I glued it to the slider knob, lubricated the tracks and had a perfectly working pot. I then re-assembled the rhythm panel and switched the unit on but there was still no sound, just a blinking LED (very modern in those days). Obviously though, the rhythm generator was now working as I could vary the blinking rate of the LED.

At that stage, I traced out the schematic diagram of one wildly oscillating gate. It was very strange, with two resistors in series between the gate's input and output. That would explain the oscillation, as the gate was forced to operate as a linear amplifier. But why?

I then discovered two capacitors in series between the same input and output. A resistor then ran from the junction between these two capacitors to the rhythm chip, while a capacitor ran to earth from the junction between the resistors. Finally, there was also a trimpot from input to output.

It's worth noting that the PCB was single-sided and that these components were spread out over an area of about 70 x 80mm. So it was a bit of a challenge to trace the circuit out and draw an accurate circuit diagram.

After redrawing the circuit a number of times, I noticed that the resistor values were all the same, as were the capacitor values. This looked very much like a double-T filter and based on the RC values used, would produce a note around 1kHz (like a snare drum?). But surely, a logic gate is a digital element and not a transistor?

The late 60s was an era of great innovation and using logic gates as amplifiers was just the "in-thing". Indeed, the logic gate and its accompanying RC circuit was supposed to operate as a damped double-T filter, with the damping level (decay) controlled by the trimpot. That is an inventive use of logic gates!

The problem is, this is a dicey design that's rather prone to wild RF oscillations. To get around this, the designer selected CMOS chips with low input to output gain and high output impedance. I replaced the CMOS ICs with older types and suddenly there was sound.

The newer CMOS gates are not going to work here and that explains why these chips were in IC sockets – so that they could be easily changed. Indeed, this might be the very last organ in existence just because of this design problem. And that's a pity because the keyboards are of very high quality and still work well, even after 50 years of standing around.

The bass pedals also work extremely well and the speaker is about 350mm in diameter and will shake the floor at full power. Now, if I could only play the thing!

the battery snap terminals but hadn't thought it significant at the time. Nevertheless, it was a clue. I cut the battery cables near the PCB, bared the ends and temporarily connected a spare battery snap to the cut wires. I then switched the unit on again and presto . . . it now worked.

Further investigation revealed that the original negative battery lead had suffered corrosion under the insulation, immediately adjacent to the battery snap terminals. As a result, it had effectively turned into a resistor which is why only 7V was being applied to the PCB.

Having established the cure, I soldered the new battery snap to the PCB and checked the unit out by comparing its readings to those on my other DMMs. It all worked as expected, so I now have an additional multimeter in my arsenal for general purpose use.

I also found an identical screw to the missing one and I replaced that while I was reassembling it.

This was an easy fix that saved a good unit from being binned – all for the sake of a 20-cent replacement battery snap. Simple fixes like this are always rewarding because, with very little effort, a useful piece of test gear is saved from going into landfill. SC

By NICHOLAS VINEN

Low Frequency Distortion Analyser

Are you concerned about the quality of your 50Hz 230VAC supply? Would you like to measure the harmonic distortion of your loudspeaker system? This unit will measure the distortion of a 50Hz or 60Hz mains waveform (via a low-voltage isolating transformer) or the distortion of any 3-20VAC sinewave signal in the range of 20Hz-10kHz, eg, the output of a midrange or bass loudspeaker.

WE TEND TO think of the 50Hz AC mains supply as a 230V RMS sinewave but if you have a look at it on an oscilloscope (see Fig.1), it is often quite distorted. A large proportion of mains loads are not resistive but reactive and since they draw current out-of-phase or in a non-sinusoidal manner, they generate a voltage across the finite impedance of the mains supply network and distort the signal.

Typical "waveform distorters" are fluorescent and gas discharge lights and devices with transformer/rectifier-based linear power supplies or non-PFC (Power Factor Correction) switchmode power supplies. These all tend to draw current only at the voltage peaks, leading to the pronounced "flat-topping" you can see in Fig.1.

Does this matter? Well, most equipment will not be affected by even quite severe levels of mains distortion but some sensitive devices could be upset. As an extreme example, there are plenty of devices which will not operate correctly from square-wave inverters and some devices won't operate from modified sinewave inverters either.

Having said that, the distortion levels of such inverters are well above the maximum allowable figure for the mains supply which is normally quoted as 5%. In our experience, a typical harmonic distortion figure is around 3% but it varies quite a bit depending on location. Interestingly, different power points in our office gave quite different readings, from 2.4-3.2%, suggesting that they are wired to different mains phases.

And yes, this analyser can be used to (indirectly) check the distortion of portable 230VAC generators and inverters. **It's safe to use because a small 3-20VAC plugpack is used as an isolation transformer** (ie, the plugpack is plugged into the generator or the mains and the plugpack's low-voltage AC output is fed into the signal input of the analyser).

So how would you know whether your mains supply is badly distorted? Well, this simple device will tell you. It can measure harmonic distortion from below 0.1% to around 33% with a bandwidth of a few kilohertz and

it's very simple to build and operate.

Some devices which may be sensitive to mains distortion include certain types of (mainly older) test equipment and medical devices. Devices with motors will still run with highly distorted mains but some may get hotter than normal. Severe harmonics, such as those present when mains tone control signals are being broadcast, can also cause transformers, motors and fluorescent light ballasts to hum or buzz audibly.

Some hifi enthusiasts also believe that AC mains waveform distortion and noise can also affect the sound quality of amplifiers and other equipment. In our experience, while control tones and some mains-borne interference may become audible, that tends to be more likely in valve amplifiers. Otherwise, typical distortion of the 50Hz (or 60Hz) mains waveform is not likely to have any effect on audio performance.

However, there is one exception. If the mains waveform is severely "flat topped" that means that its peak-to-peak value will be significantly reduced with respect to an undistorted sinewave. That in turn means that the resulting supply voltages in the amplifier can be less than they should be and that can definitely affect performance, particularly if the amplifier being driven hard.

For more information see this link: http://www.mantenimientomundial.com/sites/mm/notas/Harmonics.pdf

If you want to measure loudspeaker distortion you will need a microphone and preamplifier. The easy solution is to use the PreChamp featured in our article on "How To Do Your Own Loudspeaker Measurements" in the December 2011 issue.

How it works

Traditional audio analysers use a tunable notch filter. The filter removes the fundamental frequency (eg, 50Hz or 60Hz for a mains supply) and the remaining harmonics and noise are measured and related to the input voltage to obtain a percentage reading.

This project idea was initially suggested to us as a series of passive notch filters driven by a low-voltage transformer. The notches would be tuned to the local mains frequency (ie, 50Hz), thus removing the fundamental. The residual signal (ie, distortion components) could then be measured

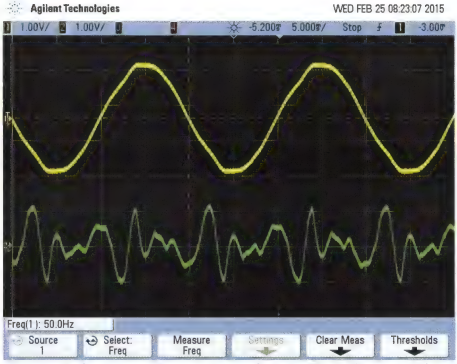


Fig.1: a typical mains waveform, as measured at our office (yellow, top) with its distortion residual (green, bottom). Not only are the peaks badly flattened but there are visible bumps along the rising and falling edges too, especially around the zero crossing points. It isn't obvious from the residual but the distortion is almost all odd-order harmonics (ie, 3rd, 5th, etc) due to the flat-topping. This is very similar to the distortion in an audio amplifier when the output is clipping.

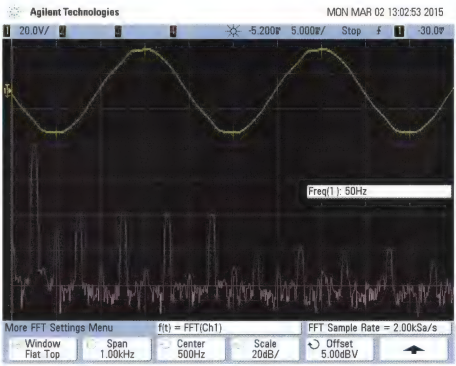


Fig.2: at top is the same distorted mains waveform as in Fig.1 with a low-pass filter applied to remove noise; below is the spectrum calculated by the scope from this data using a Fast Fourier Transform. It is configured to use the same Flat Top window as the microcontroller in this project. You can see that the third, fifth, seventh and ninth harmonics are dominant at around -39dB with a second harmonic at about -48dB. The number of harmonics shown is about the same as the micro uses to calculate total distortion.

Parts List

1 double-sided PCB, coded 04104151, 104 x 60.5mm
1 UB3 jiffy box (optional)
1 5kΩ mini horizontal trimpot (VR1)
1 28-pin DIL IC socket (for IC1)
1 9V battery snap
1 9V battery
1 piece non-conductive foam, approximately 65 x 40 x 8mm
1 PCB-mount DC socket (optional) (CON1)
1 2-way terminal block, 5.08mm spacing (CON2)
1 5-pin right-angle header (CON3) (for programming IC1)
1 2-pole 6-position rotary switch (S1)
1 knob to suit S1
2 PCB stakes
2 chassis-mount binding posts (optional, for use with case)

Semiconductors

1 PIC32MX170F256B-I/SP programmed with 0410415A.HEX (IC1)
1 78L05 100mA regulator (REG1)
2 MCP1700-3.3/TO 3.3V low-dropout regulator (REG2)
1 yellow or orange 3mm LED (LED1)
1 red 3mm LED (LED2)
1 1N4004 1A diode (D1)
1 1N5819 1A Schottky diode (D2)

Capacitors

1 220µF 25V electrolytic
3 100µF 16V electrolytic
1 10µF+ 6V tantalum or SMD ceramic
1 1µF multi-layer ceramic
3 100nF multi-layer ceramic

Resistors (0.25W, 1%)

3 100kΩ	2 470Ω
1 33kΩ	1 22Ω
3 10kΩ	1 10Ω
1 1kΩ	

with a DMM and divided by the raw transformer output voltage in order to calculate the THD+N figure as a percentage.

We investigated this concept but concluded that passive filters are too fiddly to tune and too lossy for this purpose. Tuning is a tricky issue because such filters inevitably involve capacitors which are not normally sold in tolerances better than 5%. So each notch stage would need at least one trimpot and they would all need to be tuned very close to 50Hz to get a deep enough notch for sufficient fundamental rejection.

However, the real show-stopper for the passive filter idea is its inherent signal loss and its lack of notch depth; you need a really steep notch to remove the fundamental but have no effect on the harmonics. A simulation of the required filter with ideal components showed that the first few harmonics (ie, 100Hz, 150Hz, 200Hz etc) were severely attenuated by the shoulders of the notch, making the resulting reading likely to severely underestimate the actual level of distortion.

The third harmonic at 150Hz is normally the largest component of mains distortion and a twin-T passive notch filter tuned for 50Hz is still 10dB down at this frequency. If multiple such filters were used (and it seems likely this would be required), the attenuation would be 20dB or more and this is clearly unacceptable.

We did consider using active notch filter(s) but to get the required notch depth with sufficiently little attenuation for the second harmonic at 100Hz would require a complex circuit. The alternative is to use digital signal processing with a microcontroller.

DSP software to the rescue

The DSP concept is relatively simple, even if the software is not. The output of a 9VAC or 12VAC plugpack is attenuated to give a signal of about 3.3V peak-to-peak. This is fed to the analog-to-digital converter (ADC) input of a 32-bit microcontroller. The micro digitises the signal, does some filtering to make up for its relatively low-performance internal ADC, then does a spectral analysis and determines the THD from the result.

The output from the microcontroller is a pulse width modulated (PWM) signal which is filtered to obtain a DC voltage that can be read with a multimeter or panel meter. So the circuit is really quite simple even though the software is anything but.

In fact, we use a Fast Fourier Transform (FFT) to produce a spectrum analysis of the input signal. This tells us the amplitudes of fundamental frequency and all the harmonics up to the 20th. The tallest peak will be the 50Hz fundamental and the micro can easily search for the highest peak, so frequency accuracy is not important. The distortion components (ie, the harmonics) will be at equally spaced frequencies above this peak. These calculations are performed in the frequency domain.

As hinted at earlier, the formula for computing THD (in the time domain) is to divide the RMS average of the residual signal (ie, signal minus 50Hz fundamental sinewave) by the RMS average of the fundamental sinewave itself, then take the square root of the result. It isn't hard to do this in the frequency domain, as the spectral peaks correspond to the RMS voltages of each individual sinewave component.

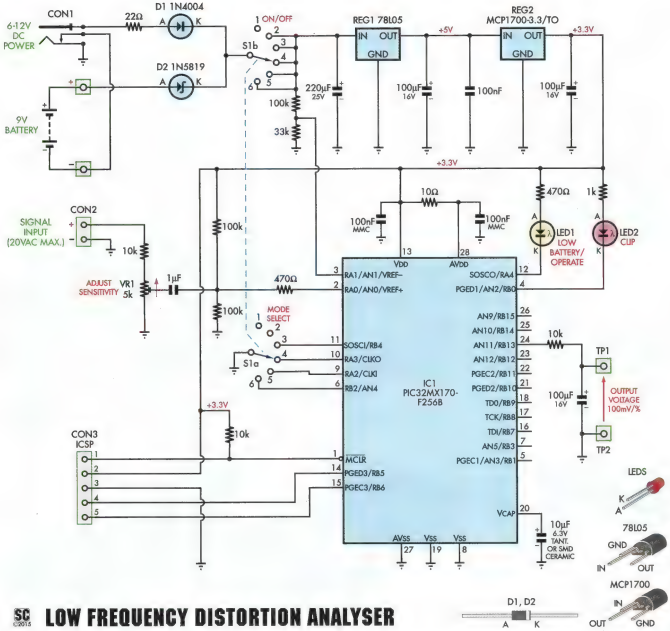
In theory, the answer is the same although the time-domain method inevitably includes any noise within the measurement bandwidth of the instrument while the spectral version gives the possibility of ignoring noise and only considering the harmonics themselves, thus giving a THD (only) measurement rather than THD+N.

In this case, it's necessary because the micro's 10-bit ADC has a lot of aliasing noise and this would cause a THD+N reading to be much too high. Also, if mains noise is going to cause any problems, it's most likely to be due to RF emissions. This would not normally contribute much to a THD+N reading, partly because the absolute power is low and partly due to the typically limited bandwidth of the measurement.

Other uses

The aforementioned distortion measurement method is sufficiently generic that it could be used for other purposes. Because the unit searches for the fundamental, the THD of any signal in the range of 20Hz-10kHz can be measured. However given that the output starts to become less accurate at lower readings (<0.1%) and the lowest reading you're likely to get is around 0.03%, it isn't suitable for measuring hifi audio amplifiers.

Having said that, it certainly should be suitable for measuring the kind of distortion that's typical for . . . ahem . . . a valve amplifier. The lowest readings the device can give are more or less in line with the best performance expected from a valve amplifier. And with solid-state amplifiers, it's good



SC LOW FREQUENCY DISTORTION ANALYSER

Fig.2: the distortion analyser circuit. There isn't much to it since most of the work is done in IC1's software. The signal is attenuated by VR1 and then biased to half-supply (1.65V) before being applied to analog input RA0. A PWM signal from pin 24 (RB13) passes through a low-pass RC filter with the reading available between TP1 and TP2. Power comes from a 9V battery or DC plugpack while rotary switch S1 provides both on/off switching and mode selection.

enough to at least check that an amplifier is operating correctly and so it might be useful for servicing work.

In order to provide relatively accurate readings at higher frequencies, the unit automatically increases its sampling rate (by reducing the amount of averaging done) when it detects that the fundamental is at a higher frequency.

Circuit description

The full circuit is shown in Fig.2. It would normally be powered from a 9V battery via Schottky reverse polarity protection diode D2 but it could be powered from a DC plugpack via diode D1. **It cannot be powered from the same 9-12VAC plugpack which is used to couple the 50Hz mains AC signal into the analyser.**

If a plugpack is used to power the Low Frequency Analyser, the 9V battery is disconnected by the socket switch, CON1. D1 provides separate reverse-polarity protection for the plugpack. The DC supply is connected to the circuit via one pole of 6-position 2-pole rotary switch S1.

Two 3-terminal regulators are connected in series to provide a 3.3V supply for the microcontroller. The first is REG1, 78L05 5V regulator which acts as a pre-regulator for 3.3V regulator REG2 which can only handle a maximum input voltage of 6V.

In practice, this two-regulator combination provides a regulated 3.3V rail (important for accuracy of the output voltage) for input voltages down to about 5V, which would mean the 9V battery was well and truly flat.

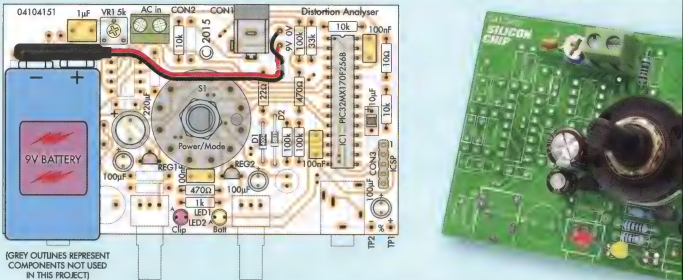


Fig.3: follow this PCB overlay diagram and the photo at right to build the Distortion Analyser. Note that many of the components are left off as this PCB was designed to be used for multiple purposes. It snaps into the side rails on a UB3 jiffy box or can be housed in a larger enclosure if a panel meter is to be fitted, to display THD readings.

So that you know if the battery has gone flat, a 100kΩ/33kΩ resistive divider allows PIC32MX17F256B microcontroller IC1 to monitor the battery voltage at its AN1 analog input (pin 3). The 3.3V rail is used as a reference and if the battery voltage drops below about 5.6V, LED1 is illuminated.

The input signal is fed in via CON2 and has a 15kΩ fixed resistive load. **This minimal loading means that a 9VAC or 12VAC transformer's output closely tracks the mains waveform, ie, the transformer itself causes minimal extra distortion.** The signal is then coupled via a 1µF capacitor and DC-biased to 1.65V (half the 3.3V supply) by a pair of 100kΩ resistors. The signal then goes to analog input AN0 (pin 2) of IC1 via a 470Ω protection resistor.

The chip uses its internal RC (resistor/capacitor) oscillator and PLL (phase locked loop) to run at 24MHz, so that its FFT calculations on the sampled data at AN0 complete fairly quickly. The ADC requires 13 clocks per sample (1 for sampling, 12 for conversion) and is run at ¼ the main clock rate, giving a sampling rate of 24MHz ÷ 13 ÷ 4 = 460kHz.

Between 1 and 16 samples are averaged, giving an effective sampling rate of between 28.75kHz and 460kHz. For a 50Hz signal (eg, mains) at 28.75kHz and a window size of 8192 samples, this means 8192 / 28750 = 285ms worth of data or just over 14 full cycles is processed at a time.

Having done the THD calculation, the micro then uses one of its internal PWM peripherals to generate a signal at output RB13 (pin 24). The associated timer period is set to 3300 so that for each increment in the PWM duty cycle value, the average output voltage increases by 1mV. This assumes an accurate 3.3V rail; the MCP1700 has an output voltage tolerance of ±0.4% at 25°C so it should be well within ±1% at normal room temperatures.

This PWM signal passes through a 10kΩ/100µF RC low-pass filter with a time constant of around one second. This gives a DC voltage to make the meter's job easier and also to smooth out any jitter in the measurement due to noise and so on. It can then be measured between TP1 and TP2.

Each time the output voltage is updated, LED1 is flashed briefly. This indicates that the unit is operating. As mentioned earlier, IC1 monitors the battery level via its AN1 input and should the battery voltage drop to a low level (before output accuracy suffers), the state of LED1 is inverted. That is, LED1 is switched on all the time, except briefly when the output voltage is updated when it flickers off.

Thus, if LED1 is on most of the time, the battery is flat and should be changed.

LED2 is used to indicate ADC overload on input AN0. For optimum performance, VR1 is adjusted to just below the level where LED2 lights. Having said that, the exact setting is not critical as long as LED2 remains off during operation; if VR1 is set a little low, it doesn't appear to affect the readings much.

Rotary switch S1a connects either pin 6 or one of pins 9-11 of IC1 to ground. With S1 in position 1, power

Features & Specifications

Input signal voltage: 3-20V RMS

Input signal frequency: 20Hz-10kHz

THD measurement range: 0.03-33%

THD measurement accuracy: typical error less than 0.1% (absolute)

Modes: total distortion %, second harmonic %, third harmonic %, even harmonic % and odd harmonic %

Power supply: 9V battery or 6-15V DC plugpack

Operating current drain: ~15mA

Low battery indicator: LED, ~5.5V threshold

is disconnected so the unit is off. IC1 can determine which of the other five positions the switch is in by enabling its weak internal pull-up current sources on these pins. If S1 is in position 2, none of these pins (6 or 9-11) is pulled low whereas positions 3-6 each pull a different pin low.

IC1 checks the state of S1 immediately after it updates its output and performs a slightly different measurement at the next update, depending on its state. In position 2, the normal THD calculation is made. In position 3, only the THD contribution from the second harmonic is read out. Similarly, position 4 reads the third harmonic only, position 5 gives the THD contribution of all even harmonics (2nd, 4th, 6th, etc) and position 6 reads only odd harmonics.

CON3, the ICSP header, is used to program IC1 and is not required if you are using a pre-programmed chip. The only remaining components in the circuit are the two supply bypass capacitors for IC1's V_{DD} and A_{VDD} rails, a 10Ω resistor to help filter its analog supply and a 10µF capacitor at pin 20 (V_{CAP}) which is used by its internal core regulator. This 10µF capacitor must be a low-ESR type (below 1Ω) which means either tantalum or ceramic.

Construction

Building this unit is straightforward with most of the parts mounted on a PCB coded 04104151. Note that there are a number of blank component locations, as this PCB was designed for other uses as well.

Fig.3 shows the parts layout on the PCB. Start by checking the resistor values with a DMM and fit them where shown. Follow with diodes D1 and D2; these are different types and are both orientated with their cathode stripes facing the bottom edge of the PCB.

Next, fit the IC socket with its notched end towards the top of the board. Check that it's sitting flat after soldering two diagonally opposite pins, then make the rest of the joints. Follow with the ceramic capacitors, trimpot VR1 and then the two regulators. Don't get the latter mixed up and note that you will probably need to crank their leads out with small pliers before mounting them so that they fit the pads.

If fitting the DC socket, do so now. Similarly, you can install pin header CON3 but note that it isn't required if you have a pre-programmed chip.

Now fit the two PCB stakes at lower right, followed by the tantalum and electrolytic capacitors. These capacitors are all polarised, with the longer (positive) leads all going towards the top of the board. If fitting CON3, lay the adjacent 100µF electrolytic capacitor over, otherwise you will have trouble plugging the PICkit programmer in.

CON2 can now go in, making sure its wire entry holes go towards the nearest edge of the board. That done, trim about 10mm from the end of switch S1's shaft, leaving it 30mm long as measured from the top of switch body. File off any burrs and check that the knob still fits, then mount S1 on the PCB.

Be careful with S1's orientation as there are two possible ways it can go in. The plastic locating spigot must go towards IC1 as shown in Fig.3

Once the switch is in, feed the battery snap leads through the two strain relief holes and solder them in place. Note that if you haven't fitted CON1, you will also need to solder a wire link between its pad nearest the edge of the board and the vertical pad immediately to its left and slightly below. This replaces CON1's internal switch. Without this, the circuit won't get any power from the battery.

The two LEDs are fitted at almost full lead length, with the base of their lenses 25mm above the top of the PCB (use a cardboard spacer). This allows them to just poke through the lid of the jiffy box. If you aren't using a jiffy box, you could just push them all the way down onto the board. Either way, both anodes (the longer leads) go towards the left.

We used a red LED for the clipping indicator (LED2, at left) and yellow for the operation/low battery indicator (LED1, at right) but you can change the colours if you want. You may need to adjust the current-limiting resistors to suit though.

You can now plug microcontroller IC1 into its socket, ensuring it has the correct orientation, ie, pin 1 towards upper left. If your chip is blank, use

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
1µF	1µF	1u0	105
100nF	0.1µF	100n	104

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	3	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	33kΩ	orange orange orange brown	orange orange black red brown
❑	3	10kΩ	brown black orange brown	brown black black red brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	2	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	22Ω	red red black brown	red red black gold brown
❑	1	10Ω	brown black black brown	brown black black gold brown

Calculating Distortion Using A Fourier Transform

Total harmonic distortion is defined as the ratio of the RMS voltage of a signal's harmonics to the RMS voltage of the signal itself (the signal normally being a sinewave). The traditional method for measuring the THD of a sinewave is to align a deep, adjustable notch filter with the fundamental frequency, measure the RMS voltage of the residual, then divide this by the RMS voltage of the signal.

However, this calculation can also be done based on a spectral analysis of the signal. Spectral analysis breaks the signal down into a series of sinewaves with various frequencies, amplitudes and phases. When these sinewave components are summed, the original signal is reconstructed.

We can find the fundamental by looking for the sinewave component with the largest amplitude and we can then find its harmonics at integer multiples of the fundamental frequency. The ratio of the sum of harmonic amplitudes to the fundamental amplitude then gives us the THD figure.

Note that this is not THD+N since we're only looking at the harmonic amplitudes and not the wideband noise (which would also be at frequencies below the fundamental and between the fundamental and harmonics).

That all sounds relatively easy but there are quite a few tricks to it. First, we need to discuss the use of the Fast Fourier Transform method which is used to convert the sampled time-domain data to frequency-domain (ie, spectral data).

The input to a Fourier Transform is typically a buffer with a power-of-two number of sample values, encoded as complex numbers. Normally the complex numbers would initially have a zero imaginary portion, ie, they are real numbers nominally in the range of -1 to 1 (we're using some tricks here to get extra performance but we'll explain them later; for now, assume that's true).

The Fourier Transform converts these complex numbers into another set of numbers of identical size, the magnitude of which indicate the amplitude of the component sinewaves at a set of evenly spaced frequencies. For example, say we have a 4096-entry buffer (2^{12}) and the sampling rate is 8192Hz.

The magnitude of the resulting complex number at index #1 indicates the amplitude of the sinewave component at 1Hz, index #2 at 2Hz and so on, up to 2047Hz (ie, half the Nyquist limit). The complex "angle" of these values indicates the relative phase of the constituent sinewaves but we aren't really interested in that.

So you might expect that if you performed an FFT transformation on a pure sinewave at say 100Hz, you would be able to read out its amplitude at index #100 and all the other values would be zero, indicating the lack of any other frequencies in the signal. However, with the naive implementation of the FFT, as well as getting a positive magnitude at index #100, you also get lesser values at index #101, index #102, etc with decreasing values. The result is similar at lower indexes, ie, #99, #98, etc.

In fact, you will get a non-zero value in every single "bin". That's because of the fact that in the 4096-sample window, the signal abruptly starts at sample #0 and ends at sample #4095. These sudden start and end transitions cause this "blurring" of the data.

Windowing

This problem is mitigated to a large extent by the practice known as "windowing" the data. This is akin to a piece of music which fades in at the start and fades out at the end – you lose the abrupt transitions at these points. There are infinitely different ways to do this (which vary by the rates of "fade-in" and "fade-out") and depending on which windowing method you use, the result has different properties.

Basically, different methods provide different compromises as to how much the "blurring" is reduced versus how much the magnitudes are altered. Popular windowing methods include Hann (also known as Hanning), Hamming, Blackman-Harris and Flat Top. If no such function is applied, this is known as a "Rectangular Window". These is an excellent description of these methods at the following URL: http://en.wikipedia.org/wiki/Window_function

The behaviour of some common windows is shown here, in images taken from that article. In each case, the left panel shows the function by which the input time-domain samples are multiplied. On the right is the sample output of an FFT for a pure sinewave with this windowing function applied. Note how slowly the function falls off from the peak with a rectangular window compared to the others.

For the task at hand, we decided to use Flat Top because this makes measuring the exact amplitude at a given frequency easy. Basically, it guarantees that even for frequencies which fall between two "bins", one of the bins will contain the correct value. The other will contain a similar or lesser value. This means we don't have to do any complex summing to determine fundamental or harmonic amplitudes. For an explanation, see: http://www.dsprelated.com/showarticle/155.php

Flat Top has worse frequency resolution than most other windowing methods however since the harmonics are spaced apart nicely (by the fundamental frequency in fact), it isn't really an issue.

But there is another, more subtle (and less discussed) issue with windowing and this is that it also causes the resulting amplitudes to fall off at higher frequencies. Failure to compensate for this will cause under-estimation of distortion

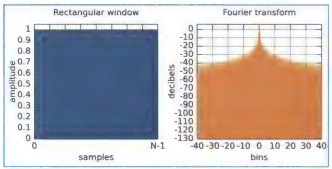
an in-circuit programmer to flash it now, via CON3. You can power the chip from the programmer if it has that capability (the PICkit3 does) – if not, apply DC power to CON1 or the battery snap.

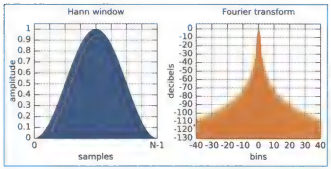
Testing

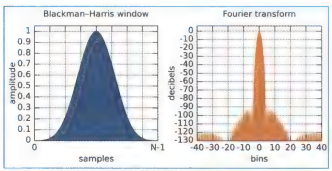
If you have a triangle-wave generator, you can test the unit quite easily. First, turn trimpot VR1 fully anti-clockwise and apply the triangle-wave to CON2 with a peak-to-peak voltage close to 5V if possible. That done, apply power, switch S1 to position 2 and turn VR1 clockwise until either LED2 lights or you reach the end-stop. If LED2 lights, turn VR1 anti-clockwise until it just turns off.

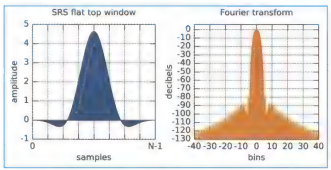
Now measure between TP1 and TP2. It may take a little while to settle but it should give a reading close to 1.2V (representing 12% distortion) and stay there. However, it may be slightly higher if your triangle-wave source is badly distorted. LED1 should flash at a few hertz, depending on the signal frequency (anywhere in the range of 20Hz-10kHz should be OK).

If you don't have a suitable signal









due to apparently reduced harmonic amplitudes.

Our simple solution to this problem was to run a Flat Top-windowed FFT on a series of sinewaves of equal amplitude, each of which was at a frequency centred on a bin, measure the resulting peak value and store its inverse in a correction table. By then multiplying the output of the FFT by this correction table, we cancel out the frequency-dependent windowing attenuation.

Having sampled the data, applied the windowing function, performed the FFT and determined the fundamental frequency, we then look for the second harmonic at twice the fundamental frequency. We handle cases where the fundamental falls between bins using an estimation function. Normally, there will be a small but definite second harmonic spike and we then look at a 50% higher frequency for the third harmonic and so on. Each harmonic spike that is found improves the accuracy of the guess for the location of the next harmonic.

It's then just a matter of summing the squares of the resulting amplitudes, then dividing this by the amplitude of the fundamental and performing a square root to give the THD result.

Improving efficiency

We said above that the input to an FFT is normally a set of complex numbers with zero imaginary components. Our FFT algorithm is a 32-bit fixed-point in-place calculation with a 4096 window size. This means the input is 4096 x 32 x 2 bits (two 32-bit numbers for the real and imaginary part of each complex number), for a total of 32KB storage required. Our micro has 64KB RAM, leaving half for other stuff.

Here the advantage of the in-place FFT becomes apparent; because the same buffer is used as the input and output and no temporary storage is required, we can have a larger window size than would otherwise be possible.

But it's actually possible to double the effective window size to 8192 samples without using any extra RAM. How you ask? Well, have a look at this explanation from Texas Instruments: http://processors.wiki.ti.com/index.php/Efficient_FFT_Computation_of_Real_Input

To start off, what you do is you take your 8192 samples and create 4096 complex numbers where the real and imaginary part of each consists of alternating sample values. Thus, the imaginary portions aren't "wasted" by being filled with zeros. You then perform a normal FFT computation.

Normally, half of the FFT output is "wasted" as the second half is identical to the first half (but reversed in order). With this method, the extra data is no longer duplicated and by convolving it with some sinewave coefficients, using the formulae provided by TI, we recover the full set of result vectors that we would have gotten with a twice-as-large window with a regular FFT.

Don't worry too much about understanding the mathematics behind this – it certainly works!

generator, you can use the same procedure with the signal fed in from a 9-12VAC plugpack instead. Expect a reading of around 300mV, ie 3%.

If LED1 doesn't flicker or the reading seems wrong, switch off and check for circuit faults. Assuming it's all OK, you can optionally do a further test if you have a sinewave generator. Apply its signal to CON2 using the same procedure as above and you should get a low voltage reading at TP1 of around 30-100mV, representing the lower limit of the distortion measurement – 0.03-0.1%, depending on how pure the sinewave is.

Note that if the unit can't find a signal at all, the output voltage goes to 0V. This will be the case if the input signal amplitude is too low, given the setting of VR1. If a signal is detected but it is grossly distorted (eg, a square wave), then the output will peg at 3.3V.

Putting it in a box

If you're planning on building the unit into the recommended UB3 jiffy box, it will snap into the integral ribs. All that's required is three holes in the lid for S1 and the two LEDs, plus some

This is the view inside the completed instrument. The PCB snaps into integral plastic ribs inside the case, while the battery is sandwiched between a piece of foam and the case lid as shown.

holes in the base for the signal input and output.

For the lid, copy the front-panel label shown in Fig.4 and use this as a drilling template. You can then download the label in PDF format from the SILICON CHIP website, print it out, laminate it and glue it to the lid. The holes can be cut out using a sharp hobby knife.

For the signal input, we drilled a hole adjacent to the location of CON2 and fitted a small rubber grommet. We then cut away a section of the grommet on the inside of the case so that the PCB would still fit properly (you probably don't need a grommet; we just wanted to make sure the leads don't fray from rubbing on the edges of the hole).

For the output, we drilled two holes 19mm (0.75-inch) apart at the right-hand end of the box (centred on that end). We then fitted binding posts and soldered two strands of ribbon cable to the binding post lugs. The other ends of these leads were then soldered to TP1 & TP2.

After passing the signal cable through the grommet and screwing it firmly into CON2, we dropped the board in the box, placing some non-conductive foam next to S1 (either side will do), connected the 9V battery and sat the battery on top of the foam. The lid was then attached which holds the battery in place and the knob the secured to S1's shaft.

Using it

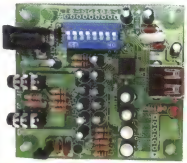
There isn't much to it, simply connect a 3-20VAC signal source (eg, an AC plugpack) to the signal input leads and turn S1 to its first stop, for the full THD measurement. Use a small flat-bladed screwdriver to readjust the sensitivity control if necessary, then connect the outputs to a DMM and calculate the distortion by dividing the voltage reading by 10 to get the percent figure. For example, a reading of 0.28V indicates 2.8% distortion.

If you want to use the device for measuring audio signals, you may wish to reduce the 10kΩ resistor value at the top of VR1 however it should not go below 470Ω (higher if you will be probing signals above 20V peak). This is to protect IC1 from excessive current flow. In this case, you may wish to connect some sort of probe or clip leads to CON2. SC

Fig.4: top lid label for the UB3 jiffy box. To make a reading, connect the signal up and simply rotate the knob to the required position. The output voltage will stabilise after a few seconds, once the unit has adjusted for the signal frequency and the output filter capacitor has finished charging.

PRODUCT SHOWCASE

Near HiFi Quality USB Recording Module with almost unlimited capacity



The LT1955 voice recording/playback chip from KitStop features a 20Hz-20kHz ±0.5dB stereo recording/playback bandwidth and up to 256 different messages, music passages or a combination of both, the length of which is limited only by the capacity of the USB memory stick used.

Applications for the LT1955 include talking books, public space annunciators, elevator cues, point-of-sale prompters, personal recording machines, background music, call-on-hold phone storage and speech laboratories.

The LT1955 chip is also available installed onto a populated USB-compatible development board.

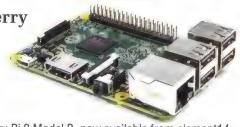
The development board features:

- Recording uses memory at the rate of 1GB per hour
- Able to play back WAV files recorded on USB sticks from other devices
- Similarly, tracks and messages recorded on the Board can be played back on other devices such as audio players or PCs
- Signals (mono only) may be recorded through the inbuilt microphone or direct via line-in ports for mono and stereo inputs

The LT1955 Evaluation Board and the LT1955 IC are available for via the KitStop website.

Contact:
Perrin, Wright & Associates
PO Box 5422, Clayton, Vic 3168
Tel: (0432) 502 755
Website: www.kitstop.com.au

New Raspberry Pi 2 Model B from element14 is 6x faster!



The new Raspberry Pi 2 Model B, now available from element14, is claimed to be six times faster than the previous model and now boasts 1GB of RAM to run bigger and more powerful projects.

The Raspberry Pi 2 features a new Broadcom BCM2836 ARMv7 Quad Core Processor powered Single Board Computer running at 900MHz, with 1GB of RAM. It boots up in less than half the time of its predecessor.

The expanded GPIO pins, advanced power management and connectivity make it possible to connect up to four USB devices, including some powered devices such as hard drives. The 40-pin GPIO enables multiple sensors, connectors and expansion boards to be added, with the first 26 pins identical to the Model A and B boards, for full backward compatibility.

The Raspberry Pi 2 include faster and more enjoyable gaming. The millions of Raspberry Pi enthusiasts will also be pleased to hear that upgrading their existing projects to benefit from the improved performance simply involves an update to the Operating System.

Since its launch in February 2012 over four million Raspberry Pi boards have been sold, while element14 has launched over 30 exclusive accessories specifically designed and manufactured to expand its usability. The element14 Community has become one of the leading websites for discussion and collaboration around Raspberry Pi projects and developments. With over 280,000 registered users, the element14 Community is the largest online community for design engineers to share ideas, knowledge and solve challenges.

The Raspberry Pi 2 Model B can be purchased direct from the element14 community for $38.00 plus GST.

Contact:
element14
72 Ferndell St, Chester Hill NSW 2162
Tel: 1300 361 005
Website: http://au.element14.com

OKW's new iPad Enclosures for industrial or commercial use

OKW's INTERFACE-TERMINAL multi-function electronic enclosures now have new front panels to enable iPad Air tablets to be securely mounted to walls or desks, or in a robust handheld enclosure to help prevent damage or even theft.

They provide a tamper-resistant, IP-40 rated housing and mounting solution for the viewing and operation of an iPad Air in communal locations such as museums, offices, factories, public buildings, laboratories and healthcare facilities. Both front panels have been designed to fit the Type I INTERFACE-TERMINAL housing.

The modular design gives the choice of either mounting the iPad flat on a wall or desk or inclining it at an angle of 20° for more comfortable viewing and operation. Robust handheld units are also available.

The front panels are available in matt anodised aluminium or ABS. The plastic panel is rated UL 94 HB. Its standard colour is Off-white (RAL 9002) but custom colours can be specified. Both panels are supplied with two attachment strips and assembly kits.

All OKW enclosures can be fully customised with CNC milling and drilling, printing or engraving of legends and logos, bespoke colours, special finishes and assembly of components.

For further details about the new iPad Air front panels and the many other OKW enclosure solutions, visit the website.

Contact:
ROLEC OKW Aust/NZ Pty Ltd
Unit 6/29 Coombes Drive Penrith NSW 2750
Tel: (02) 4722 3388 **Fax:** (02) 4722 5300
Website: www.rolec-okw.com.au

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Build It Yourself Electronics Centre

Issue: April 2015

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With USB recording!

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High Definition TV for the Car, Caravan or Boat.
This 7" wide format LCD features in-built HD tuner to receive all the latest digital Freeview channels. USB port is provided for PVR recording of shows. MP3 & video USB/SD playback. Powered by an rechargeable battery or car accessory socket. Easy to install.

Includes handy carry case!

T 2175

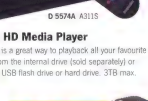
$52 SAVE 25%

9pc 1000V Rated Insulated Tool Kit
Great for electricians, technicians or anyone working on mains equipment! Includes cutters, pliers, wire strippers, 240V test driver, 5 screwdrivers, and 2 rolls of tape.

$77 SAVE 10%

D 5574A A311S

Noontec® 1080p HD Media Player
The Noontec MovieDock is a great way to playback all your favourite movies and TV shows from the internal drive (sold separately) or external storage such as USB flash drive or hard drive. 3TB max.



Ideal for tradespeople

$64.95 NEW!

D 0508

Weatherproof Battery Bank
Must have for tradies, travellers and hikers. Water and dust proof battery bank to recharge your phone on the go! 5V 1A output, 5600mAH.

Amazingly stable and portable.

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T 4704

Portable Cable Reel Stand
Lightweight & easy to move around. Suits reels up to 4000 x 430Wmm. Max reel weight 25kg.

$59.95 NEW!

P.8144

Cut energy usage!

Wi-Fi Remote Control Mains Switch
Connects to your home wi-fi and allows you to switch appliances on or off via your smartphone, iOS or Android apps available.

Great for IP based surveillance systems!

$149 NEW!

D 4212

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An 8 port gigabit switch equipped with 4 "power over ethernet" (PoE) ports designed to power 802.3af compliant devices such as IP cameras, IP telephony handsets and wireless access points. Provides up to 15W of power per port over distances up to 100m.

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Test Equipment Deals

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Q 1255

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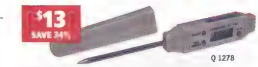
Measure wind speed & temperature easily.
A compact thermometer & anemometer with max speed of 108km/h. Great for ventilation monitoring, experiments etc. Includes battery. Very easy to use!



$13 SAVE 34%

Q 1278

Probe Thermometer
A handy instant read thermometer for kitchen or BBQ use. Also great for labs. Stainless "easy clean" probe. °C or °F, min/max hold, -40°C to +250°C. Includes battery.

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Q 1071A

Pro Autoranging DMM
Push buttons for easy one hand operation! Multifunction backlit display shows date, time, bar graph & measured reading simultaneously.
• 3 measurements per second - up to 11 min • Resistance, frequency, duty cycle, capacitance, continuity, AC/DC voltage & current • 10A rated • Includes rubber holster & test leads

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Autoranging True RMS DMM
A high accuracy digital multimeter designed for those requiring true RMS ac waveform measurement. Includes 10MHz frequency counter, capacitance and temperature measurement (probe included). Relative function, backlit LCD, USB datalogging also in-built (lead included). Cat III 600V.

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Q 1134

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Wide voltage range and high current output!

Compact & Efficient Lab Power Supplies

Bench top power supply for use in servicing, repair and design of electronics. The low noise switchmode design offers excellent regulation for high current requirements. Offers the flexibility of both wide adjustable voltage & current range. Size: 336W x 87H x 214Dmm.

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Pure AC power from your car battery!

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High Power Compact Pure Sine Wave Inverter

Pure sine wave 12V inverter with high 800W surge rating suitable for powering difficult loads, including switchmode power supplies. Fitted with USB charging output: 400W rated. Size: 200L x 108W x 60Hmm.

Charge 2 tablets at once!

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Huge 4.8A current output. Ideal for charging two phones or tablets at once.

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2 Pin DC Socket

32V 15A DC rated. 4mm cable entry. 44x44x28mm.

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30mm mounting hole. Flylead connection.

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As used on many portable appliances for caravan use.

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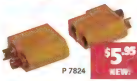
Detects and analyses voltage, cold cranking amperes, resistance and cell condition in 12V lead acid cells. Easy connection and on screen menu driven operation. Ideal for vehicle servicing or checking 12V SLA cells in battery backup systems.

Quick and accurate battery health check

Q 2120 — $169 NEW!



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XT60 Style DC Connectors

Commonly used on RC LiPo batteries.

*Relay for illustration purposes.

$4.95 YOUR VALUE!

S 4325

Relay Base With Fly Leads

An easy way to fit a relay into existing wiring looms. 180mm flyleads. Suits S 4330/2. S 4335A.

Protect your battery investment

These battery desulphators prevent sulphation from occurring on the plates of your battery - a primary cause of premature battery failure. These modules help minimise, even partially reverse sulphation. Suits standard and SLA type batteries.

Easy in-line hook up

Suits...	Part	RRP
12V under 70Ah	M 8540	$49.95
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Commonly used on RC LiPo batteries.

W 4050 — $30 PER ROLL

SAVE 20%

Ultra HD Fig 8 Cable

Great for DC power wiring. 17A Rated. 15AWG. 30m rolls.

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Monitor energy use & cut standby power. P 8134

In-built energy meter to calculates running costs! Can be switched between energy saving mode (which reduces standby power use) or standard powerboard mode. Surge protected up to 300000A!

$29.95 REDUCED!

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Uses standard automotive blade fuses. LED indicator for each circuit. 6.4mm spade terminal connections. Max 25A per circuit.

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Solderless DC Jacks

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Virtually any combination you may require in car accessory socket, Merit socket and 2.1A 5V USB charging. Each plate is supplied with two facia covers to suit your existing wallplates. Easy connection via 6.3mm spade lugs on rear.

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Ultra-Slim TV Brackets
An affordable range of TV wall brackets offering incredibly low profile.

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	32-65"	H 8165	$54.95	$42
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"Picture Hanging" TV Bracket
Mount your TV just like a picture on the wall.
Features reinforced wall mounts, steel cabling & TV support for easy cable connection.
32-55" TVs, 50kg max.

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$14.95 HALF PRICE

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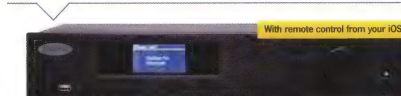
Great for smaller TV's up to 32", 200mm VESA mount. With locking bar. Max 35kg.

$35 SAVE 30%

H 8140



With remote control from your iOS or Android device.

A 2696

Access over 14,000 internet radio stations from your home hi-fi!
This stylish wireless internet radio player will perfectly compliment your existing AV system. It provides you with access to DAB+ digital radio stations, plus virtually any internet station or podcast via wireless internet (no PC required!). Plus it can stream music stored on your PC via UPnP. Size: 430x90x285mm.

$319 SAVE $80

Latest model!

A 3217B

$215 NEW!

Extend HDMI up to 100m using UTP cable.
Extends HDMI signal using economical Cat5e/6 cabling without sacrificing signal quality. IR control signals can also be relayed both ways. Supports Foxtel IQ. Includes receiver, transmitter, 2 IR targets, 2 IR emitters & power supplies.

Scale up 1080p to 4K resolution
Plus, extract digital audio from your HDMI signal along the way. A handy adaptor for 4K TV owners looking to upscale HD sources. S/PDIF audio out. Includes power supply.

HANDY!

A 3834

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16 Channel 520MHz UHF Wireless Mic Systems
New 520MHz models - work throughout Australia!
A complete wireless mic system with your choice of handheld or beltpack mic. • Plugs into existing PA systems • Crisp vocal reproduction • Ideal for clubs, restaurants & wedding ceremonies. Up to 70m range.

$299 SAVE $20

NEW

C 8867C Handheld Pack
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Lightweight, Compact 2 Ch DJ Mixer
Great for beginners and mobile DJs requiring a robust lightweight mixer. Two pairs of switchable phono and line inputs, plus stereo record and amp outputs. Bass, treble and gain adjustments. Cue crossfader makes it easy to cue upcoming tracks. Includes power supply.

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9V battery powered!

A 2620

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Powered by 9V battery or plugpack (M 9237A $17.95) this tiny mixer is perfect for karaoke or small productions. It mixes four 6.35mm mics. Robust steel case.

5.8GHz Wireless AV Sender
Great for wireless CCTV!
• Transmit stereo audio & composite video without cables from room to room • 30m range • IR sender built in • Includes transmitter, receiver & plugpacks.

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S 9359

Great for cafes and shops

A 2710

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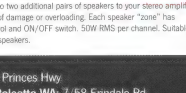
USB Background Music Player
Simply plug in a USB stick, connect the RCA output to your amplifier & press play! It even automatically loops. Requires M 9272B 12VDC plugpack $17.95.

Compact Caravan Aerial
Digital ready amplified TV antenna for great reception on the road!
Easy to install, includes cabling & power supply.



L 2002

Also great for boats!

$99.95 NEW!

Wireless sound anywhere you want it!
This wireless speaker uses the latest Bluetooth 4.0 standard with quick NFC device pairing with your smartphone or tablet. 40mm compact speaker and tuned enclosure • Hands-free phone functionality.

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A 2384

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Size	Model	RRP	Per Pair
8" 80W	C 0996A	$250pr	$200
12" 200W	C 1004A	$698pr	$560
15" 250W	C 1008A	$798pr	$640

A 4198

$169 SAVE $50

Four stereo 30W amps in one!

4 Zone 30W Amplifier

Ideal for multi-zone audio distribution. Offers 30W RMS per zone (15W per/ch) all from a unit measuring just 200mm wide! Individual volume controls. Headphone output. RCA input. **Includes power supply.**

$60 SAVE 24%

A 2630

4 Channel Headphone Amplifier

Ideal for audio monitoring in bands, music production, connects four headphones with individual level control. Stereo RCA, 3.5mm and 6.35mm TRS inputs. Includes power supply. 113x73x40mm.

$189 SAVE $40

A 1113

2x15W RMS class-D amp.

Wireless 30W Bluetooth® Amplifier

Simply hook up a pair of speakers and stream audio from your Bluetooth® smartphone or tablet up to 10m away. Infra-red remote volume, bass & treble adjustment. Includes remote control, IR target & power supply.

Educational Electronics

K 1126

$21.95 NEW!

Ages 8+

Motorised 4 in 1 Robotics Kit

Assembles 4 different robot designs which teach kids about geared movements in a practical and fun way! Requires 1xAA battery. No soldering required.

$21.95 NEW!

K 1132

Ages 8+

6 in 1 Solar Recycler Kit

Uses common household items like soft drink cans and old CDs to create fun and interesting solar powered designs. Build a robot, steam roller, CD racer, bottle yacht and more! No soldering required.

Ages 8+

$39.95 FUN KIT!

K 2204

A great starter option for the kids

30 in 1 Electronics Lab

Contains everything you need to build a range of electronic projects to encourage learning about essential principles. Requires 2 x AA batteries.

Ages 8+

K 1123

$19.95 NEW!

T4 4 in 1 Solar Robot Kit

Build a robot, t-rex dinosaur, drill vehicle and rhino beetle. Performs different movements when placed in the sun. A great intro to solar power and electronics. No soldering required.

$159 SAVE $20

K 2222

Ages 10+

300 fun projects in the one unit!

300 in 1 Spring Terminal Electronics Lab Kit

The 'Rolls-Royce' model with all the bells and whistles. Teaches you about electronics from A to Z. You will learn about electronic parts, how to read schematics, and wiring diagrams. All this, while building up to 300 projects. Provides many hours of tinkering - a great way to gradually build on your knowledge. Requires 6 x AA batteries.

Ages 8+

K 1115

$29 SAVE 17%

'Follow Me' Robot Kit

Uses four inbuilt microphones to detect sound (such as a hand clap) and moves toward it. No soldering required. Requires 4 x AAA batteries (not included).

$39.95 SAVE 20%

Ages 12+

K 1107

Robotic Arm & Claw Kit

A great introduction to basic robotics. Includes five motors allowing base rotation, shoulder, elbow and wrist motion, plus claw for picking up objects (up to 100g). Includes wired controller.

Resellers

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Kalgoorlie	Comm Systems	(08) 9091 9078

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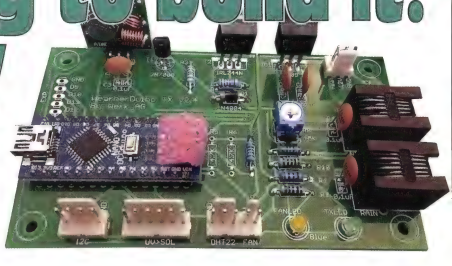
Part 2 of our quality Weather Station based on ARDUINO

Pro2 wireless weather station WeatherDuino

System designed by Armindo Caneira*
Built and written by Trevor Robinson
*www.meteocercal.info

Starting to build it: the 'TX' board



Last month, we told you how we obtained many of the specialised parts from ebay sellers – in fact, quite a number came from just a couple of them.

If you're considering building your own weather station, we'll assume you're well on the way to obtaining these parts, along with the PCBs which come from the designer in Portugal (www.meteocercal.info).

In this second instalment, we list all the parts, conveniently broken down into individual lists for each component (ie, the transmitter, receiver etc) and then we move on to building the first module – the TX (transmit) Unit.

As you can see, apart from the specialised parts, most are "garden variety" components available at virtually any electronics retailer. We understand that some of these retailers may also attempt to obtain stock of the more specialised components as well.

Building the TX unit

If you're familiar with building projects you can skip this part as it's all common practice and common sense.

If not, though, there are a few tips to keep in mind:

The soldering iron

Keep your soldering iron tip clean. Use a wet sponge (often incorporated into soldering iron stands) or a copper or brass woolly pad to regularly drag the tip over.

If you're not using the iron, turn it off – nothing kills a soldering iron tip faster than leaving it heated. And if you don't already have one, a temperature-controlled soldering station is a really good investment (particularly if you build more projects, repair devices and so on).

Beware of static

Quite a few of the components in this project can be damaged by static electricity. This can build up on you and on your tools (including the soldering iron) simply by using them – and usually you don't know about it!

If a component is supplied to you on foam, in foil or in an anti-static tube, take anti-static precautions such as earthing the workspace and yourself, making sure any tools you use are discharged and so on. It also pays to leave the component in the anti-static material until you are ready to use it.

You'll find a lot of helpful tips on the internet, courtesy of Dr Google.

Populating the PCB

These are double-sided boards so the first thing to do is work out which is the "normal" (or top) component side and which is the reverse side. Use our component overlay diagrams for this.

It's normal practice to insert the lowest height components first – obviously, resistors fall into this category. Capacitors are usually soldered in next, remembering

that electrolytic types are polarised and must be inserted into the PCB so that the "-" on the side of the component matches the "-" symbol on the PCB.

Leave diodes and other semiconductors until later, with "hardware" the last to go on.

Soldering

When soldering the components in, make sure you don't use too much heat but you need enough heat to make sure the component leads are properly soldered to the pads on both sides of the board, where appropriate.

If soldering a heat-sensitive component such as a transistor, it's better to leave as much leg length as possible because this will tend to minimise the heat getting to the transistor itself. You can also use a small clip-on heatsink (or even a crocodile clip) on each lead as you solder to further protect the device.

Also make sure you don't use too much solder and form bridges between pads – most particularly when pads are very close together. Good soldering comes with practice, practice and more practice.

Inspection

When complete, give your PCB the once-over – twice! First check your component placement, including polarities where required, against the overlay diagram. If there are any blank component positions, check that they are supposed to be – blank, that is!

If you're happy with what you've done, then use a loupe or magnifying glass to carefully inspect the soldering. Where possible, check both top and bottom joints and if in doubt, use a continuity tester (or a multimeter) to check for shorts between pins or pads. If a joint looks doubtful now, re-solder it and avoid problems later!

The miniature 433MHz transmitter module solders into the TX PCB.

Notes about the PCB and components

Normally, you won't need to install resistors labelled R5 and R6 (10kΩ, 0.25W) on the PCB, as they are for optional I²C devices that don't have internal pull-up resistors.

After installing the 20kΩ preset potentiometer, set it to its mid-point (ie, 10kΩ). This is a fine adjustment for the wind vane but once set to 10kΩ, it's unlikely to need further adjustment.

The 7809 regulator and the IRLZ44N MOSFET both come in "TO-220" packages so are easy to mix up. Refer to

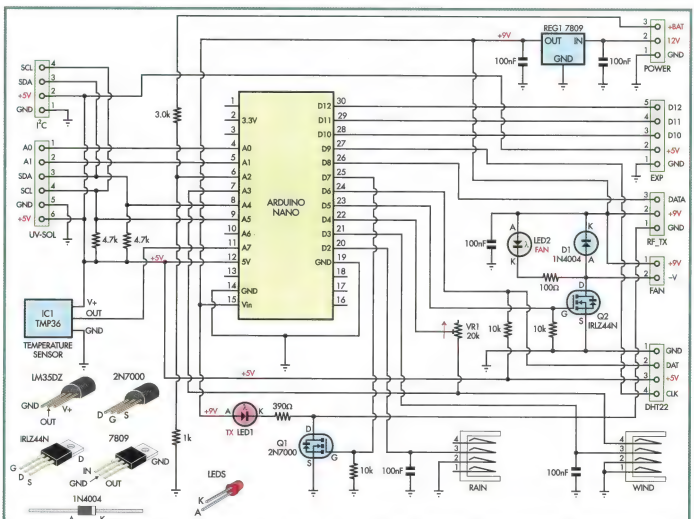


Fig.1: the circuit diagram for the first WeatherDuino module to be built, the TX (Transmitter) Module.

Parts List – TX Unit

	(Notes)
1 WeatherDuino Pro2 TX V4.0 PCB	(Notes)
1 Arduino Nano v3.0 microprocessor module	(H)
1 SHT10 digital temperature and humidity sensor module	
1 FS100A 433MHz TX module	(I)
1 433MHz antenna	(D)
1 SMA female panel connector, with pigtail	(C)
1 TMP36 temperature sensor (#)	(G)
1 case to suit	(E)
1 heatsink to suit 7809 (#)	
1 12V DC fan (optional – used only with a Stevenson Screen)	
1 power supply, 12VDC @ 1A or higher if fan used	

Connectors (both plug and socket required #)

1 3-pin polarised header (power & battery voltage sensing)
1 2-pin polarised header ("Stevenson Screen" fan)
2 4-pin RJ-12 4P4C sockets (for temperature sensors)
1 6-pin polarised header (UV solar interface)
1 5-pin header (for expansion port; optional – unused but may be used for later expansion)

Semiconductors

1 IRLZ44N N-channel MOSFET (Q2) (G)
1 2N7000 N-channel MOSFET (Q1)
1 7809 9V positive voltage regulator (REG1)
1 1N4004 rectifier diode (D1)
1 3mm red LED (LED1)
1 3mm green LED (LED2)

Capacitors

5 100nF multi-layer ceramic

Resistors (0.25W, 5% or better)

3 10kΩ 2 4.7kΩ (J) 1 3kΩ 1 1kΩ 1 390Ω 1 100Ω
1 20kΩ horizontal trimpot

(#) – See text for more information

Parts List – RX Unit

	(Notes)
1 WeatherDuino Pro2 RX PCB	(M)
1 Arduino Nano v3.0 microprocessor module	(H)
1 DS3231 real-time-clock Arduino module	(A)
1 3V lithium battery (coin cell) for RTC	
1 DHT22 temperature/humidity sensor	(A)
1 BX-RM06 ASK OOK RF receiver	(B) (K)
1 BMP180 (or BMP085) barometric pressure module	(A)
1 SMA female board connector	
1 Jumper (sets BMP module voltage)	
1 momentary pushbutton switch, NO	(E)
1 SPST pushbutton on/off switch	(E)
1 display: either ST7735 1.8" TFT, *OR* 20 x 4 alphanumeric LCD, *OR* 16 x 2 alphanumeric LCD	(A)
1 433MHz antenna	(D)
1 case to suit	(E)

Connectors (both plug and socket required #)

1 3-pin polarised header (power & battery voltage sensing)
1 2-pin header (for screen mode pushbutton switch)
1 2-pin header (for SPST switch used for program/run mode selection)
1 4-pin polarised header (for temperature sensor)
4 4-pin polarised headers (for TFT screen and backlight)
1 jumper shunt (for pressure sensor)

Semiconductors

1 2N7000 N-channel MOSFET (Q3)
1 3mm red LED (LED2)

Capacitors

1 100nF ceramic

Resistors (0.25W, 5% or better)

2 10kΩ 1 360Ω
1 120Ω (use 100nF ceramic capacitor instead if your Arduino Nano has a CH340 chipset)

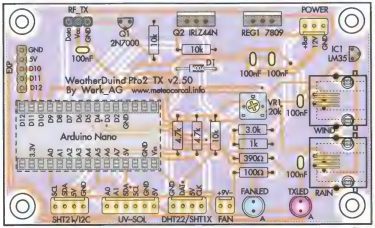
their labels and the screen printing on the PCB to get them correct! In both cases, the metal heatsink of both of these devices goes towards the edge of the PCB.

To connect the SMA pigtail GND, you have to carefully remove some of green solder-mask on the FS1000A module's PCB, near the ANT hole. Then solder the centre conductor to the "ANT" and the shielding braid to the where you removed the varnish.

When installing the Arduino Nano, stagger the soldering of the pins to avoid heat build-up. Even better, use a 30-pin socket and plug the Nano in later.

Power connection

Most constructors will power the TX unit with a 12V DC



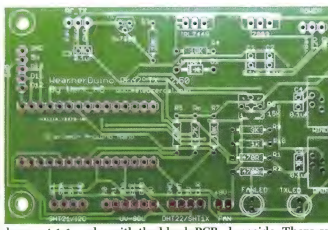


Fig.2 (left): the WeatherDuino Pro TX PCB component overlay shown at 1:1 scale, with the blank PCB alongside. There are minor differences between the prototype boards and the final production boards.

Parts List – Wireless Display Unit

(Notes)

1 WeatherDuino Pro2 wireless display PCB (includes all SMD parts already soldered on) (M)
1 5V DC power supply, fitted with mini-B USB plug
1 pushbutton switch, momentary, NO (E)
1 SMA female PCB connector (C)

Semiconductors

1 Arduino Nano (H)
1 DHT22 temperature/humidity sensor (A)
1 BX-RM06 ASK OOK 433MHz RF receiver module (B)
1 3mm red LED (LED4)
1 display – one of: ST7735 1.8" TFT,
or ILI0341 2.2" 20 x 4 alphanumeric LCD,
or ILI934 2.4" 320 x 240 alphanumeric LCD
or 20x4 LCD module OR 16 x 2 with I²C module (#)

Capacitors

1 10µF/16V tantalum
3 100nF ceramic

Resistors (0.25W, 1% metal film)

7 10kΩ 1 180Ω

(#) See text for more detail

Connectors (recommended, as it makes it a lot easier to connect and remove the PCB from its housing for later firmware updates, troubleshooting, etc).

1 5-pin polarised header (for touch screen interface)
1 SMA female board connector
1 4-pin header (for inside temperature sensor)

Optional components for Rx Unit

(Highly recommended, needed if you want to relay data to a wireless display).

1 KXD-10036 433MHz transmitter module
1 433MHz antenna
1 2.5mm DC power socket
1 2N7000 MOSFET
1 3mm green LED
1 7809 9V positive voltage regulator
1 heatsink to suit 7809

Capacitors

1 10µF 16V tantalum

Resistors (0.25W, 1% metal film)

1 10kΩ 1 470Ω (required for V4.03 PCB only)

Notes Table

– please refer to listings last month for ebay item numbers

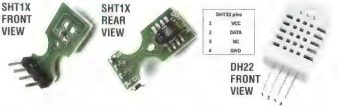
A All these came from same ebay seller.
B From supplier nominated, both pieces come together as a pair. These can be brought separately elsewhere but must match the picture as these types work best!
C All these came from same ebay seller.
D All these came from same ebay seller.
E Up to the end user to choose the best for the application/ and desired look.
F Also requires 12VDC power pack to suit (positive centre)
G All these came from same ebay seller.
H All these came from same ebay seller.
I This came from the same seller as A (above).
Please don't use the included Receiver module in this pair. It's not good (but the transmitter is good!).
J Only required if you are using the I²C connector with a device that doesn't have internal pull-up resistors on the SDA and SCL lines.
K Can be omitted if you buy the KXD-10036 RF Transmitter/Receiver modules for the optional data relay as this part is included in the kit.
M From www.meteocercal.info/forum/index.php

plugpack. But if it's not close to mains power, you could use a solar panel and 12V battery. The TX unit allows remote monitoring of the battery voltage so if using a battery, connect the +BAT terminal to the 12V battery (+) and the 12V terminal to the output of your solar charger controller. If you're using a plugpack, simply connect the +BAT and 12V terminals together.

Your TX unit should now be complete and ready for connection of the External Temperature Sensor. But first you need to attach it to a cable.

Temperature Sensor

As discussed last month, we opted for the SHT10 Temperature Sensor as we feel it offers the best "bang for buck". Others might be more accurate but are also significantly more expensive. The SHT1x and the DHT22 use a serial protocol to pass information to the Arduino microprocessor.



PCB designation	Schematic Pin	SHT1x pins	DHT 22 pins
GND	1 (GND)	-	3 or 4
DAT	2 (D6)	D	2
5V	3 (5V)	+	1
CLK	4 (D9)	S	-

The datasheet for these SHT1x sensors can be found here: www.sensirion.com/fileadmin/user_upload/customers/sensirion/Dokumente/Humidity/Sensirion_Humidity_SHT1x_Datasheet_V5.pdf

The WeatherDuino TX board also supports the SHT1X (and the SHT2X using the I²C port), so if your budget allows it, feel free to upgrade. However, if you go with the SHT2x module, you will need to visit the Meteocercal forum for the details required to use it.

The ebay reference number we gave last month will take you directly to the SHT10 which has the senor already attached to a breakout board, making it easier to connect to the TX Unit.

Sensor cable

Make up a temperature sensor cable using a 4-pin connector (eg, Jaycar HM3404) and a length of good quality 4-core cable (maximum length 5 metres). Carefully solder the pins and heatshrink the other end of the cable to the sensor pins (or use a suitable plug to connect but remember, this needs to be protected as it is out in the open).

Case Temperature sensor

The TMP26 temperature sensor gives a voltage output proportional to the temperature.

This is used only to monitor the temperature inside the TX unit case. However, it isn't essential so if you want to save a little money, this can be omitted.

Programming the Arduino Nano

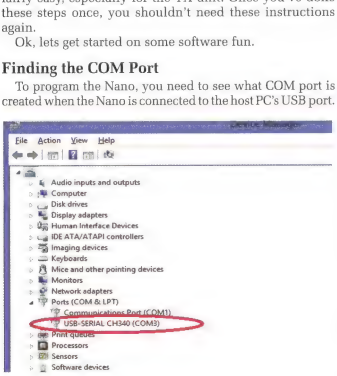
Programming is done by connecting the Nano to a PC USB port and running suitable software.

While all this looks quite complex at first, in reality it's fairly easy, especially for the TX unit. Once you've done these steps once, you shouldn't need these instructions again.

Ok, lets get started on some software fun.

Finding the COM Port

To program the Nano, you need to see what COM port is created when the Nano is connected to the host PC's USB port.



Before plugging in the Nano, open the Device Manager on the PC (Control Panel>Device Manager) and expand the "Ports (COM & LPT)" item by double clicking it.

Now plug in the Nano and you should see a COM port created like that shown below left.

If the icon beside it has an exclamation mark then you will need to install the driver.

If you purchased the Nano from the ebay supplier listed last month, the required driver for the CH340G serial adaptor is called CH341SER.zip.

You can download it from that seller's site or from this thread at the Meteocercal forum www.meteocercal.info/forum/Thread-Arduino-Nano-USB-Driver

By the way, the Serial/USB converter onboard the Nano dictates which method of reset pullup we use later on the RX/WD boards, but we will cover that in the next part of the series.

Keep the Nano plugged in and move on to the next step.

Installing and configuring the Arduino IDE

Download the Arduino integrated development environment (IDE) software from the Arduino.cc site.

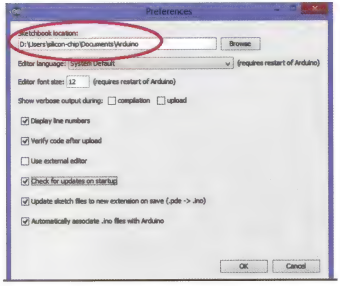
You will need the Arduino 1.5.8 BETA IDE as the code needs the extra optimisation that this beta release of the IDE gives, otherwise the code will not fit in the Nano's 32KB flash memory.

You can download the Arduino IDE here: http://arduino.cc/en/Main/Software#toc3

I'd recommend selecting and downloading the Windows Installer option from the above link (if, of course you are running Windows on this PC). Run the installer and give it a little while to install as it's quite a large program with all the built in libraries.

Once it's installed open it. Then:

1. Click File then Preferences. Take note of the Sketchbook location. The path will have the name of the current logged in user.
   This is where we'll extract the WeatherDuino software folders to.



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Radio, MP3 & WMA Player & 512MB storage, Line in, Quality Sound
* Int.mem 512MB with SD/MMC Slot
* Record Function Via Line-in
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* Inc. Charger & Leads
Size: 60mm(H) x 185mm(W) x 60mm(D)
Colour: Black

$13.50

#42681

12A 12V/24V (Auto Switch) Solar Control

Rating: 12V-12A 24V-6A
Solar Panel Controller,12V/24V auto switch High efficiency and stability,voltage drop is less than 0.2V.
Manufacturer.: JUTA

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USB Powered Multimedia Speakers

Colour: Black
RMS: 3 Watts
Drive unit 3" x 2
Output impedance 4 Ohm
Freq. response: 200Hz-18KHz
Size: 180mm(H) x 95mm(W) x 80mm(D)

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#42566

19 Pcs Drill Bit Set Titanium (1-10mm)

Sizes include - 1mm, 1.5mm, 2mm, 2.5mm, 3mm, 3.5mm,4mm, 4.5mm, 5mm, 5.5mm, 6mm, 6.5mm, 7mm, 7.5mm,8mm, 8.5mm, 9mm, 9.5mm and 10mm

$16.50

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Atlas® LCR Passive Component Analyser

In seconds the Atlas LCR will identify the type of component (inductor, capacitor or resistor), plus the value.

Resistance: 1Ω - 2MΩ (±1.0% / ±1.2Ω)
Capacitance: 0.5pF-10,000µF(±1.5% /±1.0pF)
Inductance: 1µH - 10H (±1.5% / ±1.6µH)
Peak test voltage (OC): -1.05V / +1.05V
Test frequency accuracy: ±1%
Sine purity: Typically -60dB 3rd harmonic
Dimensions: 100 x 70 x 20mm

#39668

$159.00

200W Thermoelectric (Peltier) Modules

Temperature Differential (DT) >=68 degrees C
Optimum Input Voltage (Vmax)): 24.5
Optimum Input Current (Imax):13A
Maximum Cooling Power (Qmax): 200W
Measures: 50 x 50 mm with lead wires

$39.50

2858

12V 5A 60W Switchmode Power Supply

Input: 90-264VAC
Output: 12VDC
Rated Current: 5A
Rated Power: 60W
Ripple and Noise: 100mVp-p
2.1mm DC Socket
Manufacturer: Meanwell GS60A12-P1J

$29.00

#38911

Palm Size Digital Multimeter

DC Volts Ranges: 200mV/2V/20V/200V/500V
AC Volts Ranges: 200V/500V
DC Current: 2000µA/20mA/200mA/10A
Resistance: 200R/2000R/20k/200k/20M
Size: 130 x 73.5 x 35mm
Weight:156g
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Manufacturer:KAISER EC816-200

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#42610

Rare Earth Magnets

Magnet Type: Button
Body Material :Neodymium Iron Boron

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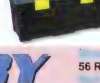
#41730	**12x3mm**	(Pack of 6)	**$2.70**
#41731	**18x3mm**	(Pack of 3)	**$3.10**



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"Display line numbers" and "Automatically associate .ino files with Arduino" check boxes. Then click OK.
3. Next click Tools, then Board. Find and Select Arduino Nano.
4. Click Tools again, and then Processor. Select ATmega328.
5. Once again click Tools, then Port and then select the COM port that you saw in the step above.

All good? Close the Arduino IDE and move to the next step.

WeatherDuino software

Now you need to download the WeatherDuino software (also called a sketch in the Arduino circles) from the Meteocercal forum site.

Here is the link to the thread for the RX and TX unit: www.meteocercal.info/forum/Thread-WeatherDuino-Pro2-RX-TX-Software-Latest-Release

Save the .zip file to wherever is convenient.

Now extract the .zip file to the location found in step 1 above. Choose OK to merge or replace the files.

If the libraries are not in the right location the IDE will throw errors when you go to compile and upload the software to the Nano.

You can manually ask the IDE to import the Libraries (menu/sketch/Import libraries) tho it's easier just to put them where the IDE is expecting to find them.

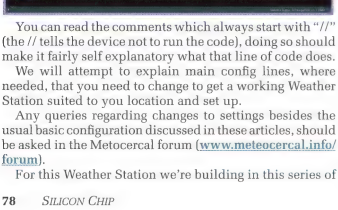
Browse to the WeatherDuino_Pro2_vXXX_XXXXXXXX in the location in step 1 above (The "x"'s will change depending on the version).

Inside there should be three folders. Open the WeatherDuino_TX_vXXX_bXXX and inside that folder should be WeatherDuino_TX_vXXX_bXXX.ino, double click that and it should open in the Arduino IDE.

Make sure it's the file with TX in the filename.

Configuring the WeatherDuino Pro TX options

Now you should be looking a window that looks like this:



You can read the comments which always start with "//" (the // tells the device not to run the code), doing so should make it fairly self explanatory what that line of code does.

We will attempt to explain main config lines, where needed, that you need to change to get a working Weather Station suited to you location and set up.

Any queries regarding changes to settings besides the usual basic configuration discussed in these articles, should be asked in the Metocercal forum (www.meteocercal.info/forum).

For this Weather Station we're building in this series of articles, nothing needs to be changed here in the TX config (shown below) unless you need to alter the Stevenson Radiation Screen fan hysteresis (if used), or if you decided against going with the SHT10 temperature sensor, then you would need to alter this line to suit:

```
#define ID1 0    // Temp / Hum data - 0 for SHT1x sensor,
                       1 for DHT22 sensor
```

for say, a DHT22 temp sensor

```
#define ID1 1    // Temp / Hum data - 0 for SHT1x sensor,
                       1 for DHT22 sensor
```

An example of WeatherDuino TX user options section of the code:

```
//--------------------------------------------------------------------------------
//  User configurable options start here.
//--------------------------------------------------------------------------------
byte StationID = 0xA1;// Must be equal to your RX Unit
                        (Value from 0x00 to 0xFF)
byte UnitID   = 0;   // If you use only one TX unit define it as UnitID = 0
                     // For a second TX unit, define it as UnitID = 1
// ---------- Let's define the data we want to send ----------
//#define ID0          // SHT21 Sensor
#define ID1 0        // Temp / Hum data - 0 for SHT1x sensor,
                     1 for DHT22 sensor
#define ID2          // Wind data
#define ID3          // Rain data
//#define ID4        // UV / SolRad data
#define ID5          // Hardware Status - System Temp, Battery
Voltage etc
byte fanOn_HiTemp = 32;  // RS Fan turn on when outside temperature
is >= than this value (°C)
byte fanOn_LowTemp = 1;  // RS Fan turn on when outside tempera-
ture is <= than this value (°C)
byte fanOn_LowWind = 2; // RS Fan turn on when Wind Average is
<= than this value (m/s)
//--------------------------------------------------------------------------------
```

Uploading the software to the WeatherDuino TX_unit

If you have made changes, we would recommend saving them with a descriptive name (file/save as).

Then it's as easy as clicking the right arrow in the IDE to compile and upload the sketch.

Normally it will work without error if configured correctly. But there's two problems that can happen:

1. The IDE will give an error that the sketch won't fit. That's usually caused by not using the latest beta version of the IDE.

2. The IDE will give an error if it can't find the libraries required. Check the location of the libraries or use the manual import function in the IDE (Sketch/Import Library).

At this point you can disconnect the TX unit from the Host computer and when you power it up from a 12VDC power pack, you should have an operating TX unit sending data packets out over 433MHz.

The green transmission LED should also blink when it does.

The sensors and instruments

Also at this point, it would be a good idea to read up on sensor and instrument placement. There are quite a

few "rules" on where specific sensors need to go to obtain correct readings.

For example, the rain sensor needs to be located away from buildings so that any rain which falls into it is not subject to amplifying or shielding; the temperature sensor should ideally be located in a "Stevenson's Screen"; wind sensors cannot be located in either a wind shadow or wind funnel and so on.

The location will also govern where you would locate your TX unit and its sensor suite – and of course the cable run lengths required.

There's plenty of great information on the internet regarding this subject. A fairly good summary can be found here: www.wunderground.com/weatherstation/installationguide.asp

Connecting the "Fine Offset" sensors:

As mentioned in the first part of this series, the TX unit supports the Fine Offset weather station sensors. These look like this:

Usually with the Fine Offset sensors, the Anemometer connects to the Wind vane via the common old flat 4-core telephone cable, using one pair. Then the Anemometer connects to the TX unit using the same cable.

The Wind vane data goes via one pair to pins 1 & 2 and the Anemometer goes via the other pair to pins 3 & 4. The board has screen printed designations showing which RJ11 socket is which.

If your sensors don't usually connect in this fashion, then you will need to make or buy a splitter of sorts. Check the schematic – it shouldn't be too difficult. You may even be able to use a phone line splitter (though not a ADSL splitter).

Wind and Rain sensors are available via ebay and some online stores.

Tip: By using multiple TX units, you can mount more than one sensor, in various locations. This is handy. for example, if your anemometer needs to be higher than the cable allows, or, another example, when you need to move the temperature sensor to a better or shadier position.

To use more than one sensor, you need to alter this code and upload it to the second TX unit (the system supports a maximum of three TX units). A third unit can only be used with temperature/humidity and solar/UV sensors, not with rain or wind sensors.

```
byte UnitID = 0; // If you use only one TX unit define it as UnitID = 0
                 // For a second TX unit, define it as UnitID = 1
```

So this part of the series was fairly easy. huh? Good, as it was bit of a warm-up as the next part gets a little more involved with the configuration of the RX unit.

And at the end of the next part you will have a fully operational weather station that's capable of sending data to the Internet! See you then. SC

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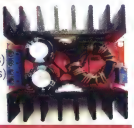

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CIRCUIT NOTEBOOK

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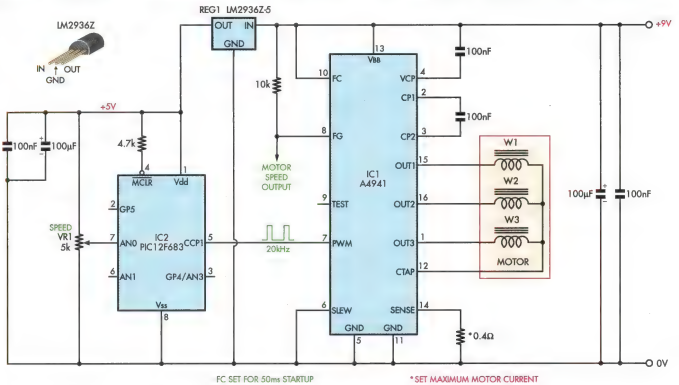

Hard drive brushless motor controller with speed control

Most of us will have an old hard disk drive in our junk boxes. If you dismantle these you will find that they contain a very high precision 3-pole brushless motor without Hall effect sensors. If you wish to run these motors then this simple circuit is for you.

More complex brushless motors contain three Hall effect sensors that tell the circuit exactly where the motor poles are in relationship to the permanent magnets. Allegro make the A4941 3-phase sensorless fan driver (available from RS Components) that senses the back-EMF from the un-energised winding produced when the motor rotates. This reduces the cost of the brushless motor as the Hall effect sensors can be omitted. The only problem is that the motor has to be rotating before the back-EMF can be sensed.

To start the motor, commutations are provided by an on-board oscillator. These commutations are part of the start-up scheme, to step the motor to generate back-EMF until legitimate back-EMF zero crossings are detected and normal back-EMF sensing commutation is achieved. A complete description of the sensing technique can be found in the A4941 data sheet.

Typical hard disk drive motors will have three or four pins for the connections to the windings. The windings are connected in a star (Y) arrangement as shown in the circuit. The motors with three pins have the start of the windings connected to them and the ones with four pins also have the common connection run out to the additional pin.

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To determine the motor pin-out, measure the resistance between the various pins. When you have the common terminal, the resistance from it to each of the three others should be the same. Those motors with three wires will still work as the IC will generate its own null point if the common is not connected.

By the way, to reverse the direction of the motor, swap over the connections to any two of the windings.

The maximum motor current is set by the 0.4Ω resistor on pin 14 of IC1. The value of this resistor is equal to 200mV divided by the maximum motor current. The motor current is 9V divided by the resistance of two motor windings added together.

Two 100nF charge pump capacitors at pins 2, 3 & 4 of IC1 provide the high voltage for the output stage drivers. The FG output at pin 8 of IC1 gives a frequency signal related to the speed of the motor.

IC1's FC (force commutation) pin (pin 10) sets the start-up time. The time is 50ms when connected to +9V, 100ms when connected to 0V and 200ms when left open (no connection). Try different settings if you find that the motor is hard to start.

The slew input, pin 6, enables or disables soft switching. It is enabled when connected to 0V and disable when left open.

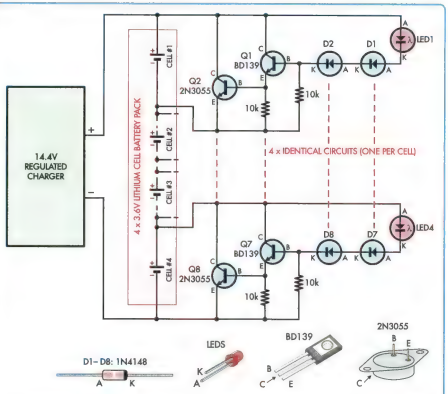
To vary the speed of rotation, PIC12F683 microcontroller IC2 is programmed to convert the DC voltage from 5kΩ potentiometer VR1 at pin 7 to a 20kHz pulse width modulated (PWM) signal on pin 5. This is fed to the PWM input, pin 7, of the A4941 (IC1). The PWM duty cycle can be varied between zero and 100%, depending on the setting of the VR1.

If you can't make your own PCB you will need a 16-pin TSSOP breakout board (available from RS Components) to mount the A4941. The IC has an exposed thermal pad on its base that needs to be soldered to an earth plane of at least one square inch to dissipate the heat generated.

To achieve this, when using the breakout board, I soldered a piece of copper foil onto the IC's base before soldering the device in place. This foil was then soldered to a larger piece of foil on the PCB containing the rest of the components.

The software, *PWMMotorControl.hex*, is available for download from the Silicon Chip website.

Les Kerr,
Ashby, NSW. ($75)



Lithium battery cell equaliser

While lithium batteries of all types have big capacity advantages over other rechargeables, it is most important that each cell in a battery stack is charged up to the same voltage. So every lithium cell needs an equaliser and while these are usually incorporated into lithium battery charger controllers, if you are making up a battery from individual cells and charging them with a simple circuit, you need a separate equaliser for each cell, as shown in the accompanying circuit.

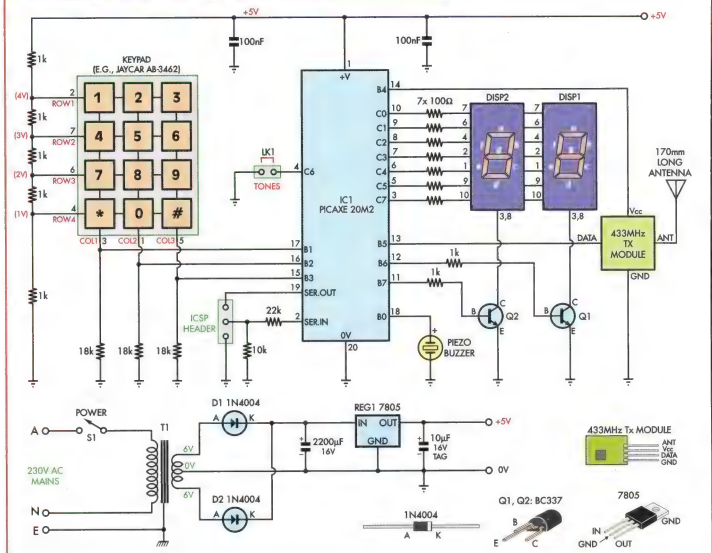
In effect, the equaliser is just a brute-force shunt regulator. So in this case, the battery is charged to 14.4V and each cell has an accompanying shunt regulator which limits the cell voltage to a maximum of about 3.6V.

Each equaliser comprises a Darlington-connected transistor pair, two silicon diodes and a red LED. It works like a rugged zener diode, with the limit voltage set by the total of the forward voltages of the red LED, the two diodes and the two base-emitter junctions of the transistors. Note that the forward voltages of both the diodes and the transistors will be lower than normal (ie, less than 0.6V) because they operating at quite a low current, to give a total of about 3.6V. If you have lithium cells which require a higher end-point voltage, add another series silicon diode.

So to sum up, as the cells begin charging, each cell equaliser/shunt regulator will have negligible effect but as it approaches the limiting voltage for its associated cell, the equaliser will progressively bypass more current around the cell, until negligible current is actually going into the cell. This shunting action will mean that transistor Q2 will dissipate a significant amount of power, depending the current output of the charger. Hence, Q2 may need a substantial heatsink.

For example, if the charger delivers 2A, the dissipation in Q2 will be 7.2W and four equalisers will dissipate around 30W.

David Francis,
Kilburn, SA. ($45)



PICAXE-based next number display system

This system is for business owners and displays numbers matching the last two digits on numbered tickets or dockets, to determine the order clients or customers will be served. This system is suitable for use in waiting rooms, service counters and in fast-food outlets.

The design is in two parts: (1) a wall-mounted "display unit" with multi-tone alarm and jumbo LED display; and (2) a desk-mounted control unit with a keypad and small LED display. Ticket numbers between (00) and (99) are supported by using 2-digit 7-segment displays.

Both parts are based on a PICAXE-20M2 microcontroller (IC1 & IC2) and they operate in the UHF band using pre-assembled 433MHz wireless modules. The numbers are transmitted using eight bytes of Manchester encoded data, containing both a 5-byte "security code" and a 3-byte "control code". The data is transmitted using the "rfout" command and received using the "rfin" command.

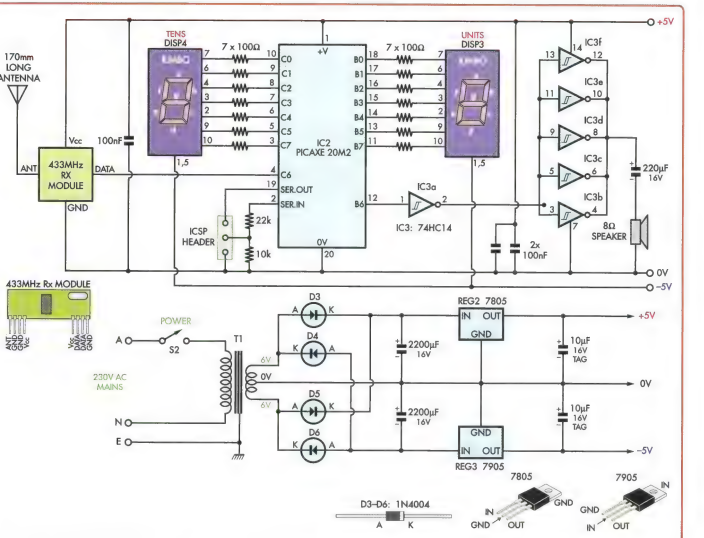
The units may be placed up to 20 metres apart and do not require any interconnecting cable. The program notes give more details, in particular for changing the default "security code".

The control unit employs IC1 and a ZW-3100 (TX) transmitter module. The small 7-segment display is multiplexed using transistors Q1 & Q2 to sink the common cathode pins, while seven 100Ω current-limiting resistors directly drive the anode pins.

Ian Robertson is this month's winner of a $150 gift voucher from Rare & Forbes

The keypad connects to the analog input pins 15-17 of IC1. The program is able to detect individual keys using the voltage levels present on the resistor divider feeding the keypad. Fitting a jumper on LK1 will increase the number of alarm tones played from two to four.

There are two ways to change the displayed numbers. First, you can add "one" to the existing number by pressing the * key (step) followed by the # key (send). Alternatively, to select any other number, you simply press two



number keys (00-99) followed by the # key (send).

Numbers are transmitted by turning on output pin 14 of IC1 to power the TX module's V_{CC} pin, then output pin13 of IC1 sends Manchester encoded data to the T_X module's DAT pin. Each key press is accompanied by a beep from the 3.3kHz piezo buzzer on pin 18 of IC1.

The display unit employs IC2 and a ZW-3102 (RX) receiver module. The 7-segment display is driven by 14 microprocessor output pins using 100Ω current limiting resistors.

Display multiplexing was not used as the "rfin" command monitoring the RX receiver module's DAT pin prevents the normal display scanning process from running. The alarm tones are generated in the software and sent to output pin 12 of IC2 and then to 74HC14 buffer stage IC3 which drives the capacitor-coupled 8-ohm loudspeaker.

The Manchester encoded data is received by the RX module and fed to input pin 4 of IC2. The received data has the "security code" tested before displaying the next number and sounding the alarm tones based on information in the control code.

The wireless transmitter and receiver modules will each require a suitable antenna, the simplest being is a length of stiff plastic coated hook-up wire 170mm long. Depending on the enclosure dimensions, the antenna wire may be left straight or coiled into a spiral.

The control unit and display unit circuits each employ a transformer-based power supply, with both having a 7805 3-terminal regulator while the display unit also has a 7905 3-terminal regulator. The jumbo display segments each have four LEDs in series (forward voltage drop 8V) and this requires the full rail-to-rail voltage of 10V DC.

Note that each regulator requires a small heatsink (Jaycar HH8502 or similar).

The displays used on the prototype were ZD1855 (small) and ZD1850 (Jumbo) from Jaycar. Other types could be substituted but the pin numbers may not be the same. The ability to directly drive the Jumbo displays was tested by continually displaying "88" for many hours while checking that the microcontroller remained cool and operated normally.

The microcontrollers each have ICSP headers for programming, with pin 2 as the serial input and pin 19 as the serial output. Use a special PICAXE serial or USB cable and download *nxcontrol_20m2.bas* to the control unit and *nxdisplay_20m2.bas* to the display unit from the SILICON CHIP website.

Ian Robertson,
Engadine, NSW.

Vintage Radio

By Ian Batty

The AWA 897P: Australia's first transistor radio

Designated the model 897P, Australia's first transistor radio was developed by AWA and first marketed in November 1957. It uses seven transistors, is built onto a metal chassis and uses the same case as its valve predecessor.

WITH THE centenary of Amalgamated Wireless Association's listing on the Sydney Stock Exchange, it seems timely to review their first transistor radio. Formed as a result of the rivalry between the German Telefunken and British Marconi companies, AWA has been a pioneering presence in radio and electronics here in Australia and around the world.

The first chairman, Hugh Denison, eventually made way for the better-known Ernest Fisk. Fisk's later knighthood and towering presence eventually extended to the familiar "Fisk Radiola" badges on many of the company's radios and even to the naming of the former Imperial Wireless Chain station as "Fiskville". For a more complete history on this, see the Historical Radio Society of Australia's *Radio Waves*, July 2013.

Early transistor radios

Regency (USA) marketed the first successful all-transistor radio in 1954, designated the TR-1 (SILICON CHIP, April 2013). Given the stupendous engineering task (a learning "cliff" rather than a "curve"), AWA's offering of the 897P in November 1957 is remarkable. The initial offering used a mix of "2N" and "OC" transistor types, the latter echoing AWA's early association with German company Telefunken.

The CSIRO had begun investigating semiconductors in 1953, initially with the assistance of Bell Laboratories. Dr Louis Davies had spent six weeks at Bell Labs and came back from the US armed with two essential precursors to making transistors: the technologies for purifying germanium and for growing single crystals of germanium.

A subsequent symposium attracted the attention of industry, rather as the original Bell Labs seminars had in the USA. Although all the "big four" Australian companies attended, it was the work of Ted Watt and Henry Banks that led to AWA starting local production in 1958. Watt and Banks had attended an engineering "apprenticeship" at RCA and their efforts were pivotal in AWA's entry to the local market.

The 897P transistor radio used an existing valve portable case design from the model 581PZ. Like many sets of the era, it also used a pressed and punched metal chassis and the parts were all installed by hand. It's quite similar the RCA Victor Transistor Seven, even down to the 2-gang volume control (the RCA set was described in the October 1956 issue of *Radio, TV and Hobbies*).

Two restorations

This article summarises two restorations, as I was very generously loaned a number of 897 variants by the HRSA's Ray Gillett. And while on the subject of variants, the original 897P used RCA 2N219 (converter) and 2N218 transistors in the RF/IF section and Telefunken OC602/604 types in the audio stages. By contrast, the later 897PX/PY/PZ used all RCA types, with 2N408 & 2N270 types now in the audio amplifier. These are all

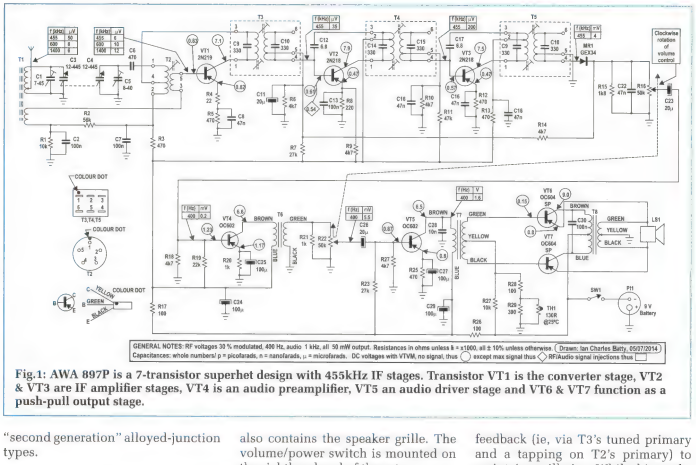


Fig.1: AWA 897P is a 7-transistor superhet design with 455kHz IF stages. Transistor VT1 is the converter stage, VT2 & VT3 are IF amplifier stages, VT4 is an audio preamplifier, VT5 an audio driver stage and VT6 & VT7 function as a push-pull output stage.

"second generation" alloyed-junction types.

The 897P: first look

As stated, AWA's 897P uses a pressed and punched metal chassis just like the Bush TR82C (SILICON CHIP, September 2013). It uses seven transistors, five of which are fitted into chassis-mounted rubber grommets with their leads then wired to adjacent solder tags.

By contrast, the two output transistors are held in heatsink clips which are screw-mounted on the underside of the chassis. This differs from the later PX, PY & PZ models which (strangely) also have their output transistors mounted in rubber grommets, defeating any possibility of heatsinking.

Unfortunately, the grommet-mounting technique means that the transistor leads are underneath the chassis. This means that unless the chassis is removed, the only circuit access, either for measurement or signal injection, is at the aerial coil, the volume control and speaker terminals.

As shown in the photos, the chassis is mounted in a substantial leather case, with the wrap-around shell closed off by stitched-on ends. The front dial turns easily with a direct drive. It sits within the front escutcheon which also contains the speaker grille. The volume/power switch is mounted on the righthand end of the set.

897P circuit details

Fig.1 shows the circuit details of the AWA 897P. Many of its components were common to the valve era and apart from the the transistors and the low-voltage electrolytic capacitors, they appear much the same as those found in portable battery valve sets.

Some models use the classic Philips tuning gang with rounded edges on its frame, brass plates and identical aerial and oscillator sections. The 897P and 897PY models use gangs with 445pF per section and a 470pF padder, while the 897PZ and 897PX models use 385pF sections and a 420pF padder. There are also minor mechanical differences, with the 897PZ and 897PX models using a different dial scale.

The circuit itself is a fairly conventional 7-transistor superhet design. The RF signal is picked up by antenna rod T1 and tuned by C3, one section of the tuning gang. The other section, C4, tunes the local oscillator. The tuned RF signal is then fed to the base of PNP transistor VT1 via coil T2.

VT1, a 2N219, is the converter stage (ie, a combined local oscillator and mixer) and this uses collector-base feedback (ie, via T3's tuned primary and a tapping on T2's primary) to maintain oscillation. While this works reliably, it does increase the amount of local oscillator (LO) radiation back out through the antenna rod.

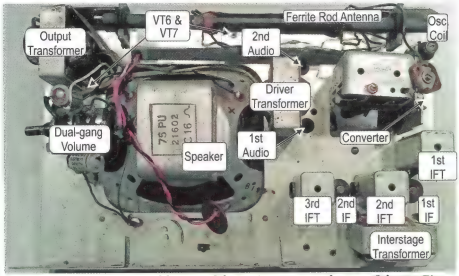
The mixer's output feeds the primary of the first IF transformer (T3). This uses a tapped secondary winding to match into the low base impedance of the first IF amplifier.

The two following IF transformers use tapped primaries and secondaries, with VT2 & VT3 (both 2N218 transistors) functioning as IF amplifiers.

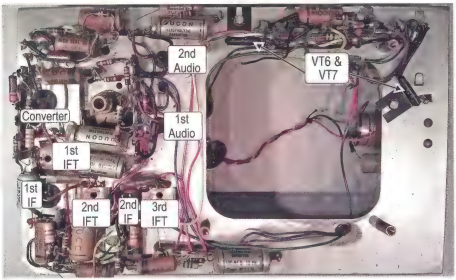
The two IF amplifiers operate similarly to those in most other sets. AGC action is applied to the first IF amplifier stage (VT2) alone, reducing base bias and thus the total collector current on strong signals. In common with other designs, reducing the collector current reduces current gain and thus the stage gain.

The applied AGC voltage (at VT2's base) is quite small, with the base bias dropping by only about 70mV at full signal. This is much less than in many other sets and is due to the voltage divider connected to VT2's emitter.

Instead of allowing the emitter voltage to also drop with incoming AGC (and thus "softening" the response somewhat like a remote cut-off valve),



This view shows the general layout of the major parts on the top of the 897P's chassis. Transistors VT1-VT5 were mounted by pushing them into rubber grommets from underneath the chassis.



Unlike VT1-VT5, the two OC604 transistors used in the push-pull output stage (VT6 & VT7) were attached to the underside of the chassis using metal clamps. Note the point-to-point wiring technique used to assemble the circuit.

VT2's emitter voltage is held nearly constant. This allows the 70mV drop in base voltage to take VT2 from its normal forward-bias value of around 130mV down to virtual cut-off at 90mV, much like a sharp cut-off valve characteristic. So because of the emitter voltage divider, don't expect to measure signal strength by the fall in VT2's emitter voltage.

The second IF stage operates with fixed bias (as usual). Note that both IF amplifiers are neutralised (using C12 & C17) to prevent instability due to collector-base feedback.

The demodulator uses a conventional diode (MR1) and this feeds audio to volume control R16. It also feeds a DC voltage back into the bias network for the first IF amplifier, in common with other designs. Stronger signals reduce the bias on the first IF, thus controlling its gain. As with all AGC systems, the net effect is to keep the audio signal fairly constant with varying RF signal strengths.

Audio stages

The 897P uses three audio stages: preamplifier stage VT4, driver stage VT5 and a Class-B push-pull output stage based on VT6 & VT7. In common with the Raytheon T-2500 and the Bush TR82 radios, the audio section uses transformer coupling. While this adds complexity and potentially reduces both high-frequency and low-frequency audio response, transformer coupling gives optimal power gain and thus improves sensitivity.

As an aside, this design choice implies that the set's RF/IF gain was less than optimal and that the deficiency was compensated for in the audio section.

The biasing in the audio preamplifier and driver stages is similar to that used in the IF amplifiers and works identically. However, larger emitter bypass capacitors are used so that they are effective at audio frequencies.

The set is unusual in using a 2-gang volume control and the "original" 897P model is readily identified by this feature and the use of "OC" series transistors in the audio section. But why use a 2-gang volume control? The articles in the HRSA's *Radio Waves* for July 2013 give two possible reasons: (1) to prevent overloading and breakthrough at low volume with strong signals and (2) to reduce the effects of preamplifier noise.

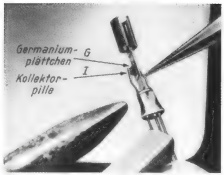
So which of the two is correct, or are they both correct? Well, bypassing the second volume control pot (R22) still resulted in effective control but made the set noisy at low volume. On the other hand, reinstating R22 and bypassing R16 solved the noise problem but caused serious audio clipping and distortion on strong signals. So the answer is that both of the possible reasons given for using a 2-gang volume control are correct.

The output stage uses a conventional transformer-coupled Class-B push-pull circuit based on VT6 & VT7. As in the Bush TR82C, feedback is applied from the speaker to each output transistor's emitter terminal.

In addition, the output stage uses a voltage divider to give about 160mV of base bias to each output transistor. In common with other Australian designs, the lower end of this divider includes a 130Ω NTC thermistor (ie, its resistance falls as the temperature increases).

The combined effect of the thermistor and transistor characteristics ensures a fairly constant collector current in the output stage, regardless of temperature. This arrangement minimises crossover distortion and protects the output transistors from thermal runaway (due to increasing current), thereby saving them from damage due to overheating.

The output stage drives a large 5 x 7-inch oval speaker, which gives good



This internal view of Telefunken's OC604Spez transistor shows the metal half-cyclinder (at top) that was used for heatsinking.

efficiency and volume. Power came from a single Eveready 276P 9V battery and this was capable of powering the set for some 300-plus hours with normal use.

The OC604Spez

The most obvious difference between the 897P and its successors is its use of Telefunken "OC" series audio transistors. Both the OC602 small-signal and OC604 output types use glass encapsulation. This glass encapsulation provides the hermetic seal that's vital for germanium devices but it impedes heat dissipation.

Telefunken's answer to this was the OC604Spez(ial) transistor, a glass-encapsulated type with internal heat-sinking that allows it to deliver up to 500mW from a 6V supply. As shown in the above photo, the heatsink consists of a metal half-cylinder that's attached to the base slice (the "Germanium-plattchen").

879PX/PY/PZ differences

By contrast, the PX/PY/PZ models use RCA-derived 2N408 transistors for the audio preamp and driver stages and 2N270 types for the push-pull output stage. Despite this, these variants perform similarly to the 897P.

Apart from that, they're recognisable because they also have their output transistors mounted in grommets. The other visible difference is the 897P's use of a Philips-style tuning gang with rounded corners in its frame compared to the more common square-cornered types.

Restoring an 879PX

As it came to me, the 897PX set had a "scratchy" volume control pot and there was no audio output. A quick check of the DC voltages revealed that all was OK in this department so the capacitors THEN came under suspicion. I needed many millivolts of signal at the volume control to get even a "squeak" of output and further checks showed that coupling capacitor C26 (20µF) was open-circuit, as was its companion C23.

Replacing both these capacitors immediately brought the set to life. Further checks then revealed that it had an audio sensitivity of about 200µV for 50mW of output, which is excellent.

Audio response?

What about the audio response? In a word, it was "rubbish" with a response of only about 190Hz to 1.3kHz. That just had to be wrong. My chief suspects were the two top-cut capacitors, ie, C28 (10nF) across the driver transformer's primary and C30 (100nF) across the output transformer's primary. De-soldering both dramatically increased the high-frequency response of the audio stages to 13kHz.

Replacing both capacitors restricted the response to 2kHz. This was quite acceptable, especially given the RF/IF section's bandwidth of about ±1.7kHz. As an aside, removing C28 extended the frequency response to about 6kHz but worsened the set's weak-signal noise figure by over 3dB. So it appears that the heavy "top-cut" technique was a quick-and-dirty way to improve the subjective performance.

One thing of note is that this set has an unused connection on the ferrite rod. It turned out to be an "aerial terminal" tap on the tuned winding and provided a convenient direct signal injection point for testing.

Now for the 897P

When I obtained the 897P, I found an envelope containing a paper inside the case headed "Freddy's Hire Purchase Contract for AWA Tranny 24-12-1957". This was proof positive that this set was indeed made in 1957. The contract, with Industrial Acceptance Corporation, shows a total amount payable of £52 13s or about $105.30 before adjusting for inflation.

In today's money, after inflation is taken into account, that's about $1500 – double the cost of a high-end smartphone. The purchaser was obligated to pay off the set over a period of 19 months.

Cosmetically, my 897P came to me with its leather case in poor condition.

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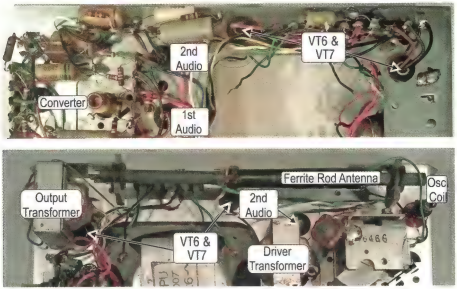

These two photos show sections of the 897PZ chassis. Unlike the 897P, this model used 2N270 output transistors which were mounted in grommets, just like VT1-VT5. The other visible difference is the 897PZ's use of a "non-Philips" tuning gang with square edges.

The leather was dull, though not badly scratched, and the stitching on one of the end cheeks had degraded, allowing the end to detach.

The case would have been machine-stitched during manufacture but I was able to locate hemp cord at a local craft shop of the same thickness as the original. After removing the original thread, I was able to counter-stitch and restore the case to its original appearance.

Electrically, the set was completely dead, apart from an audible turn-on/turn-off "click". The reason for this wasn't hard to determine – audio transformer T7 had an open-circuit primary. This was rather odd since it's a low-voltage, low-power item.

Replacing this transformer with a similar inter-stage transformer restored the set to life.

How good is it?

As noted above, the frequency response is around 190-1900Hz from the volume control to the speaker and around 210-1600Hz from the antenna to the speaker. Removing that pesky 10nF top-cut capacitor (C28) from VT5's collector extended the response to around 2.6kHz, and the difference in quality was quite noticeable.

The audio performance was otherwise quite good: at 10mW output and 400 Hz, the total harmonic distortion was just 2%, while at 50mW, the distortion was about 3.3%. This rises to around 8% as the set just begins clipping at 220mW output and is 12% for 250mW. Removing the output stage's feedback gave a worst-case figure of 8% distortion at just 50mW output.

The Pye Jetliner transistor radio described in the September 2014 issue has a diode-biased output stage and was able to maintain low distortion down to 50% battery voltage, with little evidence of crossover distortion. By contrast, the 897 is unable to cope nearly as well with falling battery voltage because it uses voltage-divider biasing. As a result, it gives audible crossover distortion when the supply is down to 5V. At this voltage, it clipped at an output of just 50mW.

The 897's selectivity is ±13kHz at 60dB down, reflecting the presence of three double-tuned IF transformers. Although the 897, like the TR82C, uses four audio stages, the 897's design fails to exceed the TR82C's performance, achieving 250μV/metre at 600 kHz and 150μV/m at 1400kHz with the volume control adjusted for a signal-to-noise ratio (S/N) of 20dB.

At full gain, the model 897 achieved 125μV/m at 1400kHz with an S/N of 17dB (note: all inputs are for 50mW output and 30% modulated at 400Hz). Given that Bush's TR82C is a later design using alloy-diffused AF116/117 transistors in the RF/IF section, the 897 (which uses alloy-junction transistors) performs quite well, especially as it was AWA's first transistor radio.

The AGC control is average and a 26dB signal increase from 60μV to 1200μV at the aerial terminal gives a 6dB increase in the audio output. The only reservation is that this set went into violent oscillation with a radiated signal strength much above 30mV/m.

Graham Moore (*Radio Waves*, July 2013) notes the "sharp cut-off" characteristics of a transistor AGC circuit and the 897, with its emitter tied to about 0.47V by voltage divider R8 & R9, certainly exhibits this.

By contrast, most sets use a single emitter resistor to ground, allowing something closer to a medium/remote cut-off. With an IF stage gain of about 30dB, applying AGC only to the first IF can't reduce the stage gain by any more than 30dB before the transistor is left with virtually zero collector current.

Basically, in order to achieve greater AGC range, the converter must also be controlled, either by using an auxiliary diode circuit as in the Pye Jetliner or by applying AGC to a mixer that's fed by a separate local oscillator.

The 4-valve predecessor

When I dusted off a somewhat sorry-looking 4-valve AWA 581PZ and applied power, I was rewarded with absolute silence. I'll leave its restoration details for another article. However, when I did eventually get it working, the 581PZ (which looks just like the 897P) had a sensitivity of about 360μV/m at 600kHz and 250μV/m at 1400kHz.

So the 897 appears to have roughly double the sensitivity. In practical terms though, the two sets would have almost identical performance except on the lab bench. I expect that the 581PZ's audio performance (output power, distortion and frequency response) will be similar to that of its all-transistor 897 successor.

Acknowledgments

Many thanks to Ray Gillett of the HRSA for his very generous loan of a half-dozen variants of the 897.

Further reading

(1) For a more complete history of AWA, see *Radio Waves*, July 2013.
(2) For more detail on the 897P, see the July 2013 *Radio Waves* articles by Graham Moore and Ian Malcolm.
(3) For more detail on early Australian transistor manufacture, see Mark P. D. Burgess' article – go to https://sites.google.com/site/transistorhistory/ and navigate to Australian semiconductor manufacturers. SC

Keysight MSO-X 3104T oscilloscope has a touch screen

By Nicholas Vinen

This updated version of Keysight's midrange scope adds a number of new features, including a touch-screen, without a price increase. Nor is there any need to return the unit to a service centre to upgrade the bandwidth all the way from 100MHz to 1GHz.

AS YOU MAY have noticed, Agilent's test equipment division has now been renamed to Keysight. So this unit is the immediate successor to the 3000A-series scope that we reviewed in the April 2011 issue. That unit dramatically raised scope performance within the budget of advanced hobbyists, educational institutions and freshly minted engineers. By that we primarily refer to its astounding waveform update rate of one million per second. When the 3000A-series was launched, a typical competitor had an update rate of around 10,000 per second.

The new 3000T-series has the same specification and still leads its class, although not by as much as the 3000A did in 2011; its appearance forced competitors to "lift their game", so to speak. Even so, Keysight's "MegaZoom IV" ASIC (application specific integrated circuit) technology has kept them in the lead. So even though this is an update to a scope released three years ago, it's still state-of-the-art. The additional features only serve to sweeten the deal.

Hardware upgrades

While the most obvious change with the 3000T is the touch screen, there are quite a few other improvements. Sampling rate for all bandwidths is now 5GHz compared to 4GHz for the 3000A (except for the 1GHz model) and 4Mpoints segment memory is now standard rather than being an extra-cost option.

All models come with 500MHz passive probes. This makes it easier to upgrade the bandwidth via software key; otherwise you would need to buy new probes. The logic analyser cable has also been improved, now being thinner, lighter and more flexible, so it's easier to work with.

Timebase stability is now 1.6ppm

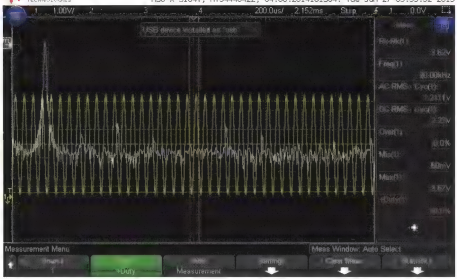

Fig.1: this demonstrates the display of eight different measurements at the right side of the screen. The touch-screen controls to drag the measurements around and access other displays on the sidebar are visible above them. Here the new FFT mode (now separate from "math") is enabled.

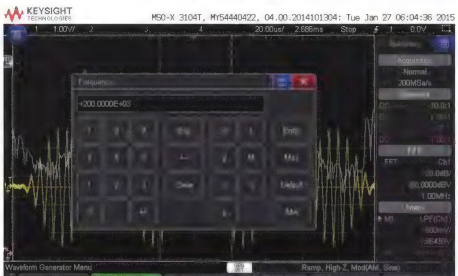

Fig.2: thanks to the touch-screen, it's now possible to input figures such as signal generator frequency using an on-screen numeric keypad.

compared to 25ppm for the older model and the calibration period is three years rather than two.

Software improvements

There are many software improvements in the new model. Our favourite is that you can now turn off the channel information in the sidebar, making room for up to eight measurements at a time. Hallelujah! See Fig.1.

Since there is now a touch-screen, that means an alphanumeric keypad can be used for entering values such as waveform generator output frequency (see Fig.2). This is a great feature. It also allows for zone-based triggering; you draw a box on the screen and it will trigger whenever the waveform crosses into that box. This is quite handy for searching for occasional out-of-spec signal glitches.

The "Advanced math" option now comes as standard – another money saver and quite a useful feature. Also, the built-in counter (which can be used for accurate frequency measurements etc) has eight digits rather than five.

Some of the major software improvements have been made to the spectral analysis (FFT function). This function now has a dedicated front-panel button and can be enabled simultaneously with one of the "math" options, whereas before you could have only one or the other. The FFT display is now correlated with the time domain, so that as you scroll through the traces, the FFT display updates to show the spectrum of the data visible on the screen.

This is a feature previously seen mainly in "Mixed Domain Oscilloscopes". While this FFT feature does not quite have the performance you get with an MDO or dedicated spectrum analyser, it is one step closer and much more useful than the FFT function in most scopes. Its dynamic range can exceed 70dB, depending on how the data is being sampled.

The FFT now has a peak search feature, akin to the cursors on a spectrum analyser and will display a list of the peaks with their frequency and power. It can also do averaging on the spectral data (a common feature in spectrum analysers but not scopes) as well as minimum/maximum hold.

The serial protocol decoding options have been expanded, adding three new automotive protocols to its already extensive list: CAN-FD (CAN with flexible data rate), CAN-dbc (CAN with symbolic triggering and decoding) and SAE J2716 SENTbus.

The scope's user interface has been revamped to take advantage of the touch-screen, although you can still perform all the functions without it if desired (there's even a button to disable it). These changes include the ability to drag various controls and displays out to their own "window", such as the DVM readout, measurements, channel summary, numeric keypad etc.

Given the relatively limited screen space and the fact that most of it is taken up by the graticule, in our opinion this is not that useful although there are occasions where we would use it.

Features

Our April 2011 review was specifically on the MSO-X 2024A although we did cover the MSO-X 3000A-series which was launched simultaneously and which had many similarities.

Both the MSO-X 2000A and 3000A series (including the new 3000T) can be had with either two or four analog channels, with or without a logic analyser and with bandwidths from 100MHz up to 500MHz and 1GHz respectively. The base models (ie, 2-channel 100MHz) are quite affordable and since they can be upgraded later, give purchasers both an attractive starting price and an upgrade path.

The bandwidth can be upgraded at

any time and the cost is now just the difference in price between the two models. The logic analyser (ie, digital inputs) can also be added to non-MSO models. However, two-channel models can not be upgraded to four channels so that is a decision that must be made up-front. There are also many software options that can be added to the scope later, including the single-channel arbitrary waveform generator.

The main differences between the 2000-series and 3000-series are waveform update rate (50k/sec vs 1M/sec), number of logic analyser channels (8 vs 16), sampling rate (2GS/sec vs 5GS/sec), maximum bandwidth (500MHz vs 1GHz) and some software options are only available on the 3000-series.

The 3000A-series scopes are still available but there's no point in buying one any more since the 3000T has all the same features and more.

The rear panel of the demo unit, which was supplied with the optional LAN & VGA interface module installed. Besides this, the only connectors are the mains input, USB host & device ports and BNC external trigger inputs and outputs. There's also a Kensington lock and calibration access hole.

Impressions

Overall, the MSO-X 3104T is a joy to use. Its interface is responsive and the fast update rate is very noticeable. This is especially true if you have averaging enabled as the fast acquisition rate means that enough waveforms are captured to update the average after a change in timebase, so that it stabilises very quickly. While the screen isn't as large as higher-end scopes, it's sufficiently large that it doesn't feel cramped and the graduated intensity display gives an excellent picture, especially for smooth waveforms (ie, with little noise).

The controls are generally intuitive, with separate vertical controls for each channel plus six soft buttons below the screen to control most functions, in combination with the dedicated mode buttons. Overall it is an improvement compared to earlier Agilent DSO models and is among the more logically laid-out scope interfaces we've used.

The front panel button layout on the 3104T has been changed only slightly compared to the 3000A-series, with the Serial button function replaced by FFT, an added illuminated "Zone" button above the general purpose knob and an added illuminated "Touch" button to enable/disable the touch-screen.

If we look hard for something to criticise, while maximum vertical sensitivity is slightly better than average at 4mV/div (5mV/div being quite typical), there are now low-cost DSOs available which will do 1mV/div or even 500µV/div. While this sort of sensitivity isn't often called for, it is handy to have. Sometimes when we're probing for low level signals (eg, from a microphone) we have to resort to using 1:1 probes and even then, there are times when more sensitivity would be worthwhile.

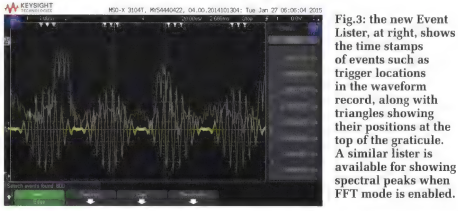

Fig.3: the new Event Lister, at right, shows the time stamps of events such as trigger locations in the waveform record, along with triangles showing their positions at the top of the graticule. A similar lister is available for showing spectral peaks when FFT mode is enabled.

We should point out that while this scope does have 2mV/div and 1mV/div settings, they are just a "software zoom" on the 4mV/div signal. Perhaps Keysight would have had difficulty getting such sensitivity with the higher bandwidths and this would have significantly increased the unit cost. But we hope to see a larger range of input sensitivity in future models.

Conclusion

I was so impressed with the 3000-series scopes after our 2011 review that I subsequently purchased an MSO-X 3024A for use at home (although it spends most of its time at our office!). The MSO-X 3000T-series is even better again; I wish it had been available at the time so I could have gotten all these extra features but I don't regret the purchase!

Despite the intervening four years, the situation hasn't changed; these scopes still offer the best bang-for-your-buck in their segment with a combination of ease of use, very high performance, upgradeability, a suite of great software options and a good starting price. Yes, you can buy a decent mixed signal scope for well under $1000 these days but it won't come close to matching the performance of the Keysight offerings.

Prices for the DSO-X/MSO-X 3000-AT series range from $3759 + GST (DSOX3012T; 100MHz, two analog channels) to $17281+GST (MSOX-3104T; 1GHz, four analog + 16 digital channels). For enquiries or to purchase a scope, contact Trio Test & Measurement at sales@triotest.com.au, visit www.triotest.com.au or phone 1300 853 407. SC

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Remote volume control project is obsolete

I bought the Remote Volume Control for HiFi systems kit (SILICON CHIP, May & June 1993) from Jaycar 18 years ago and if it's not still available I'd like to get the notes anyway! Please advise if the kit is still available or if any circuit info can be found. (R. Q., via email).

● The kit is no longer available and we suspect you'll find it difficult to get many of the parts. We've published a more recent digital volume control design, the Remote Volume Control & Preamplifier Module, in the February and March 2007 issues. It uses more modern parts but even those are becoming difficult to get.

Our more recent volume control projects have used motorised pots which readers seem to prefer.

The original articles can be purchased from SILICON CHIP.

Car or boat computer project

I would like to build the GPS Car Computer project (SILICON CHIP, January & February 2010) which was marketed as kit K1133 by Altronics but is now discontinued. Alternatively, I don't mind adopting the Boat GPS computer (SILICON CHIP, October 2010) which is available as kit K1143 from Altronics but the hurdle I am facing is the need to preset a determined speed for alarms and for the speed to be displayed in km/h rather than knots. (P. O., via email).

● Good idea. The circuits for the GPS Car Computer and GPS Boat Computer are very similar. You could build the Boat Computer kit, make a few small component modifications (if necessary) and reprogram the chip with the software for the Car Computer. If you can't reprogram it, you can send it to us and pay $10 to have it re-programmed and posted back to you. Or you can buy a new chip from us, already programmed for $15 + postage.

Phone dialler for burglar alarms

Back in April 2003 I built the Burglar alarm dialler and it worked well. I have now resurrected it to act as an alarm for my wife who is an invalid and sometimes falls from her wheelchair. I am triggering the alarm with a remote doorbell. The pushbutton is around her neck and the speaker output is connected to the alarm input with DIP switches S1/3 and S1/2 in the closed position.

This works well and when triggered rings my mobile phone and then there is the problem that unless I answer the phone the alarm does not reset, as I understand it. Of course it only needs to operate once and I come straight home if I am local or get someone to assist her, ambulance etc. Is there a way that I can fit a switch to reset the alarm when I want to and can you also suggest a way to connect the doorbell to the power supply as I am using two batteries at the moment? I am loath to rely on the alarm too much at present which means that I cannot leave her alone.

And just recently, after my wife came home from hospital, I discovered that the unit no longer worked. Thinking that possibly the PIC may have lost its memory I purchased a new programmed chip from SILICON CHIP, fitted it and then I found that Windows 7 did not have the Hyperterminal program installed. According to Microsoft, Vista or XP were the last to have it, therefore I could not program the new PIC chip or check the old PIC chip. I have tried the Hilgraeve Hyperterminal for Windows 7 but I could not get it to work.

Furby Motor Is Conventional Permanent Magnet Type

I'm curious to know if the motor in the classic Furby from 1998 to 2000 is a magnetic one. I can't find any information on the sprung copper leaves that transfer power to the commutator. If the parts are spring-loaded, perhaps the copper leaves come in contact with it in the same way brushes do.

Also, it's interesting that the conductive grease used makes the classic Furby smell "electrical" (he smells of wires). I learned that this "wiry" odour is known as an "electric motor" smell which occurs if the toy has been operating continuously for awhile. Perhaps this conductive grease gets sticky over time which might explain why older Furbys have trouble starting up.

Once a Furby of mine smelled of a chemical plastic odour from a prolonged jam caused by the eye mechanisms freezing. Luckily, he only got slightly warm around the motor and nothing was damaged. Is this what happens in all jams with a hum? (B. C., via email).

● All electric motors work by the interaction of magnetic fields. And yes, a Furby has an electric motor. It has a permanent magnet field and brushes and a commutator to feed the current to the rotating armature.

We published an article entitled "Inside a Furby" in our May 2000 issue. Most small electric motors will give an "electric motor" smell which is partly due to the sparking between the brushes and commutator. This sparking generates some ozone and also causes carbonisation of any lubricant close the commutator.

Also, heat in the motor coils causes the wiring insulation (varnish) to contribute to the electric motor smell. When a motor is stalled, it will hum (due to the magnetic field) and if the stalling continues, the motor often burns out, the wiring varnish is vaporised and it certainly does stink.

Is there any other way I can program this PIC? Or can you assist me in any way to get this device up and running again as I can't leave my wife alone at present in case a problem arises? (N. B., via email).

● The PIC16F84 is a very old micro and does seem to lose its EEPROM memory so you are right in first reprogramming the settings via the terminal. This hyperterminal client is supposed to work on Windows 7 and it has details on how to install it. See http://digitizor.com/2009/08/29/how-to-install-the-winxp-hyperterminal-client-on-windows-vista-or-windows-7-free/

There does not appear to be any way to reset the alarm without ringing back. Neither automatic nor manual modes allow for this. However, it should be possible to have a power switch that you can add to power off the alarm (ie, switch off the 5V to IC1 for a second or so and then re-power it so that the alarm is reset due to a power-up reset. Alternatively, you can momentarily connect pin 4 of IC1 to ground to reset it.

With respect to powering the doorbell, since it runs on about 3V, you could run it from the 5V supply by using a string of three diodes in series to drop the 5V down to about 3V.

Hiccup in understanding Burp Charger

I have just built the Burp Charger from the March 2014 edition using a kit from Jaycar. Having just read through the article again, it does not detail how you turn the burp function on. Is DIP switch 4 to be turned ON for the Burp function? There are some setup tables in the Jaycar printout at the end which seem to indicate that DIP switch 4 is the Burp function. (F. W., via email).

● Yes, it is DIP switch S4 that needs to be on (closed) for Burp charging. Refer to the table for switch S2 in the circuit and also in the specifications section under Burp discharge.

Temperature switch has drift

I have built up the High Range Adjustable Temperature Switch with LCD (SILICON CHIP, May 2012) but I find it drifts overnight by 6-8°C. I am using it in an oven on a boat that we are living on full time.

You may think, so how is the drift going to affect baking? Well, it will not in the scheme of things but when the oven is not used the readout should reflect the actual cold temperature (of the oven). So overnight as the air temperature drops, the readout goes up. I have tried a wire short across the input to read the ambient so as to eliminate the thermocouple and we still get this change, though it is not as great. (I. N., via email).

● Check that REF1 and REF2 give the required 2.49V (measured between TP GND and TP2 for REF2 and between TP2 and TP1 for REF1). Also note that if using the LED display module, the temperature from the regulator will be read by IC1, the cold junction compensation component. The LCD module draws much less current and so this will not cause REG1 to run hot.

Frequency switch for a one-cylinder engine

I have built the Frequency Switch project (SILICON CHIP, June 2007) and I want to use it to switch at a predetermined RPM on a single-cylinder engine with a CDI unit. What is the recommended way to obtain the pulse signal for a system like this?

Victa Electronic Ignition Module

I would like to enquire about one of my passions – the restoration of "golden era" Victa 2-stroke motor mowers. I realise this may not be very well received judging by some of the letters and Publisher's Letters of late, but here goes. The golden era of Australia's own Victa mowers extends, in my opinion, from the mid-1960s to the end of the full crank series 70/80 engines in 1984 when Victa introduced the half crank Power Torque engines.

Most of those early engines used the normal points/condenser/ignition coil flywheel magneto system that has proven very reliable over the years. Towards the end of this era, some models were fitted with a 2-terminal "electronic ignition module" that replaced the points and condenser completely but retained the same coil and flywheel magnets. The module has only two terminals, one going to earth (the metal case) with one side of the coil primary winding and the other going to the "live" side of the coil primary winding. The "kill" switch wire is also connected here and shorts it to earth to stop the engine.

It would be interesting to know what this device is and how it knows what the timing is without the points to trigger/break the primary circuit at the correct time etc. These devices are available to buy from spare parts stockists but it would be interesting to know what the device is and if it is a stock standard electronic part, only encapsulated in a metal case. It is possible to convert an engine with points and condenser to this system by rewiring and removing the condenser and points completely, making it, arguably, more reliable still? Any information will be gladly received. (P. C., via email).

● As far as we are aware, the electronic module acts as a direct points replacement. Instead of the points being opened via a cam, the module would be triggered by the flywheel magnets to drive probably a transistor that would be conducting unless triggered to cause the transistor to momentarily switch off (go open as in points). The magneto generates a high voltage to charge the coil and fires when the transistor (or original points) open.

Whether the module will work correctly or at the right firing point may depend on the magneto's magnet positioning and trigger polarity required for the module (ie, whether triggered on a north or south magnet pole).

The kill switch when closed shorts the live side of the coil's primary to ground, preventing the magneto charging the coil. That is the same as having the points or module transistor remaining in conduction or closed.

Inside the electronic module would be some form of magnetic trigger (Hall Effect device) or coil. That signal would be used to momentarily open the conducting transistor by pulling its base to ground – see www.mowersgalore.com.au/spare-parts/mower-parts/electrical/coils-and-accessories/victa/

Substitute For Currawong Power Transformer

I have almost completed the Currawong Valve Stereo Amplifier but I am having a problem obtaing the Altronics MC5337 toroidal transformer. This is disappointing as I have already spent over $250 with another $200 in two weeks for the valves.

Is there an alternative? I found one on the internet from NSW Photonage – 160VA, 37 + 37 + 15 + 15 + 12 + 12V. Could this be used in lieu of the two toroidals as it has the 12V included? (R. W., via email).

● Unfortunately, the Chinese supplier of this transformer has discontinued it which is inconvenient for everyone concerned with this popular project. In essence, you have three options:

(1) Use a 300VA toroidal transformer but the plinth will have to be made taller. A suitable transformer would be Altronics MC5545 with the two 45V and two 15V windings connected in series. This would allow for a total output of 120V which would give a slight improvement in output power.

(2) Use the 160VA Altronics M5345 in combination with a separate smaller transformer (15-18V) in series. The smaller transformer would need to be able to handle the full load current though of at least 1A. This might be a bit of a squeeze although the 18V transformer could be quite small (eg, a 30VA toroid).

(3) Use one of these 160VA transformers from element14:

http://au.element14.com/multicomp/mcta160-55/transformer-toroidal-2-x-55v-160va/dp/9530703 and

http://au.element14.com/multicomp/vtx-146-160-155/transformer-160va-2x-55v/dp/1675081

No extra windings are necessary as the two secondaries combined produce ~110VAC which is sufficient.

The engine is a Honda Rancher ATV and there is no tachometer. There is a pulse signal driven off the flywheel that triggers the CDI and the CDI is separate to the coil which has a supply side and a ground side and the high tension spark side. (P. J., via email).

● The input to the Frequency Switch would connect to the pulse signal that is present at the CDI input. If the Frequency Switch does not trigger off this, change the 3.3kΩ resistor at pin 11 of IC1 to a smaller value. A value of 1kΩ should increase sensitivity to 672mV rather than the original 1.8V with the 3.3kΩ resistor.

Switch function query on remote control switch

I have completed building the UHF Remote Controlled Mains Switch as published in your February 2008 issue. What I would like to know is what switch S4 does. I would like to change the time from the switched time by adjusting S3, leave it, and run continuous mode by switching outside the case using the push of the button. Can this be done? Does S4 do this? (R. M., via email).

● S4 is a manual on/off switch. If you do not want the timer to operate, set S3 to position 0. This causes the mains to switch on continuously and off continuously with each alternate pressing of S4. Presumably, this is just what you are wanting it to do.

LM386 power output confusion

One of my customers raised the question of the output power of the LM386 used in the Champ project (Silicon Chip, February 1994). The text states that it is a maximum of 500mW at 9V. Fig.3 shows various supply voltages, output power and dissipation.

I cannot make out the chip used in the published article and the current TI data sheet states: LM386N-1 6V/8R/325mW typical, LM386N-3 9V/8R/700mW typical. Can you please advise? (J. B., via email).

● The power output graphs for an 8-ohm load are shown in Fig.3 of the Champ article. They show the maximum power output as 325mW for 6V and 700mW for 9V at the 10% distortion level. The article quotes it as 500mW at 9V into 8-ohms and this is a more realistic power estimate where distortion is less than 3% and it is expected that this power can be delivered into 8-ohms with a 9V supply with a -1 or -3 device under music signals.

Given that the -3 version is now cheaper than the -1 version, this would be the preferred option. The -1 version was used in the original Champ prototype.

Regarding the different power output ratings, these are for a continuous sinewave signal: LM386N-1 6V/8R/325mW typical; LM386N-3 9V/8R/700mW typical.

Note that the 325mW rating for the -1 device and the 700mW rating for the -3 device are for different supply voltages and so are not easily compared.

Search for power controller circuit

I have lost an old issue of Silicon Chip which described a 240VAC universal motor controller for power tools. This design used a TL494 PWM chip and a BUP50 IGBT to make a very simple and good power controller. Could you tell me which issue this was this? (L. G., via email).

● We have searched through our issues that describe 240VAC universal motor speed controls and cannot find one that used the TL494 and BUP50. Actually, we don't think that BUP50 is a valid IGBT type number.

The closest is the November 1997 full-wave speed controller that used a BUP213 IGBT but did not use a TL494. The other is the May 2009 version that used a FGA25N120 IGBT. Our latest controller and the one we recommend is from February 2014.

We have described 12/24VDC motor controllers that use the TL494 and a Mosfet (but not an IGBT) but these don't fit the 240VAC universal motor requirement.

Garbage bin reminder is confused

I have had my Garbage Bin Reminder (Silicon Chip, January 2013) working for some time and I noticed that things did not seem correct when I finished it. Unfortunately, I didn't have the time to play with it then.

Recently, I had to change the battery and I noticed that the programming steps don't work the way you have stated, eg, do you keep the Clear All/Program button pressed all the time if you want to exclude a LED and press that LED button?

I have noticed that the LEDs don't flash once when I hold the Clear All/Program button but do so when I

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press the Clear All/Program for more than six seconds and then release it. If I then press the LED button to be excluded, after a few seconds it will flash and go off.

The other query is are the LEDs supposed to flash differently for weekly and alternate week/fortnightly reminders? And what is the Clear/Prgm button on the front panel used for as it not mentioned anywhere in the notes? Finally, has the firmware been updated from 1911112A? (R. S., via email).

● The actual way the reminders are set is complicated due to the fact that the set-up is just with switches and LED indication, rather than via a more expensive alphanumerical display that would make schedule programming easier.

The steps detailed on pages 60 and 61 of the January 2013 issue do detail the schedule programming procedure. Both weekly and fortnightly settings have the LED flash once. The Clear All/Program button is held for 6s with

continued page 96

Notes & Errata

6-Digit Retro Nixie Clock Mk2, February-March 2015: the articles stated that GPS modules with RS-232 output levels were not suitable for use. However, we have now managed to incorporate support for such modules into the final software.

Note that a resistor of around 4.7-10kΩ must be placed in series with the GPS module's TX line (ie, the wire to pin 3 of CON7, marked "TX" on the PCB) to avoid damaging the microcontroller. The micro will auto-detect inversion state and baud rate (4800 or 9600).

Note also that there is no pull-up resistor on the MCLR pin (pin 1) of IC1; while the data sheet suggests one may be necessary, we have found it works fine without. If you want to add one, it can be soldered between pins 1 & 2 of CON3.

Currawong 2 x 10W Stereo Valve Amplifier (November 2014-January 2015): in the November 2014 issue on page 32, circuit diagram Fig.2 shows T1's secondary voltages incorrectly. The two bottom windings should be shown as 15VAC, not 37VAC.

Ask Silicon Chip

. . . continued from page 95

the LEDs then each flashing once in sequence.

Continue to hold the Clear All/Program switch when you need to disable an indicator and press its corresponding Clear/Prgm button as detailed in step 2. Note that there is not just a single Clear/Prgm button but one associated with each indicator LED. In other words, the Clear/Prgm buttons are located with each LED and are used to enable or disable an indicator LED.

The Clear All/Program switch, when briefly pressed for under 6s, is used to clear the flashing "bin-out" LEDs once you put these bins out for collection.

There are no software updates for this design.

1.5V power supply wanted

I have a voltage sensitive transmitter that is powered by a single AA battery. As the battery ages the transmitter becomes unstable.

I want to use the Tx in my car and run it from the vehicle battery. Have you ever produced a stable 12V to 1.5V supply that I could use? I have been looking at a simple circuit using a voltage regulator but find that voltage regulators only go down to 5V. The required current consumption is negligible. (K. J., via email).

● You can use an LM317 to provide a 1.25V supply directly or slightly increase this using a couple of resistors. The Adjust-to-Out terminal resistor value should be 120Ω or 100Ω to ensure sufficient minimum current for the regulator.

Alternatively, a shunt regulator consisting of a resistor connected in series with three 1N4148 or 1N4004 diodes across the 12V rail will give a nominal 1.5V supply across the diodes. If the transmitter's current drain is minimal (less than 5mA), then a 1kΩ 0.5W resistor can be used. SC

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